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MECHANIZATION OF AGRICULTURE: MARKET DYNAMICS IN BANGLADESH, NEPAL, RUSSIAN FEDERATION AND VIET NAM

ESCAP
CSAM
Centre for Sustainable Agricultural Mechanization

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For further information on this policy paper, please address your enquiries to:

Dr. Yutong Li
Head, Centre for Sustainable Agricultural Mechanization (CSAM)
Economic and Social Commission for Asia and the Pacific (ESCAP) Email: li78@un.org

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List of Abbreviations and Acronyms

CSAM	Centre for Sustainable Agricultural Mechanization
ESCAP	Economic and Social Commission for Asia and the Pacific
ReCAMA	Regional Council of Agricultural Machinery Associations in Asia and the Pacific
SDGs	Sustainable Development Goals
GDP	Gross Domestic Product
FDI	Foreign Direct Investment
JVs	Joint Ventures
FAO	Food and Agriculture Organization
CA	Conservation Agriculture
R&D	Research and Development
R&M	Repair and Maintenance

Bangladesh

AFP	Axial Flow Pump
BADC	Bangladesh Agricultural Development Corporation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BRRI	Bangladesh Rice Research Institute
CRI	Centre for Research and Information
CSAM	Centre for Sustainable Agricultural Mechanization
DAE	Department of Agricultural Extension
DTW	Deep Tube Well
ESCAP	Economic and Social Commission for Asia and the Pacific
GDP	Gross Domestic Product
FDI	Foreign Direct Investment
GCA	Gross Cropped Area
GED	General Economic Division
kW	Kilowatt
LLP	Low Lift Pump
LSP	Local Service Provider
MFI	Micro Finance Institution

MoA	Ministry of Agriculture
MSP	Machinery Service Provider
MT	Million ton
PT	Power Tiller
QT	Quantity
R&D	Research and Development
STW	Shallow Tube Well
UNFAO	Food and Agriculture Organization of the United Nations
2WT	Two-Wheel Tractor
4WT	Four-Wheel Tractor

Nepal

AGDP	Agriculture Gross Domestic Product
CBS	Central Bureau of Statistics
CHCs	Custom Hiring Centers
CSISA	Cereal Systems Initiative for South Asia
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
HP	Horse Power
kWh	Kilo-Watt Hour
LI-BIRD	Local Initiatives for Biodiversity, Research and Development
MoF	Ministry of Finance
MoALD	Ministry of Agriculture and Livestock Development
NAMEA	Nepal Agricultural Machinery Entrepreneurs Association
PMAMP	Prime Minister's Agriculture Modernization Project
RCT	Resources Conservation Technology
R&D	Research and Development
2WT	Two-Wheel Tractor
4WT	Four-Wheel Tractor

Russian Federation

FEDSTAT	Unified Interdepartmental Information and Statistical System
GDP	Gross Domestic Product
HP	Horse Power
JSC	Joint Stock Company
R&D	Research and Development
ROSSPETSMASH	Russian Association of Specialized Machinery and Equipment Manufacturers

ROSSPETSMASH STAT	Statistical Portal of Russian Association of Specialized Machinery and Equipment Manufacturers
ROSSTAT	Federal State Statistics Service
RSHB	Russian Agricultural Bank
VDMA Landtecknik	Mechanical Engineering Industry Association (Germany)
USSR	Union of Soviet Socialist Republics

Viet Nam

ASEAN	Association of Southeast Asian Nations
CPTPP	Comprehensive and Progressive Agreement for Trans-Pacific Partnership
DCRD	Department of Economic Cooperation and Rural Development (Ministry of Agriculture and Rural Development)
DOVECO	Dong Giao Foodstuff Export Joint Stock Company
EU	European Union
EVFTA	European-Vietnam Free Trade Agreement
GDP	Gross Domestic Product
HAGL Agrico	Hoang Anh Gia Lai International Agriculture Company
HP	Horse Power
HS	Harmonized Commodity Description and Coding System
KAMICO	Korea Agricultural Machinery Industry Corporation
LAMICO	Long An Machinery Industry Joint Stock Company
MARD	Ministry of Agriculture and Rural Development
SINCO	SINCO Mechanical Company
THACO	Truong Hai Group
THAGRICO	Truong Hai Agriculture Joint Stock Company
USD	United States Dollar
VEAM	Vietnam Engines and Agricultural Machinery Corporation
VietGAP	Vietnamese Good Agricultural Practices

Executive Summary

The 2021 United Nations Food Systems Summit recognized the pivotal role of agriculture and food systems in achieving global sustainable development. Sustainable agricultural mechanization stands out as a significant driver towards the achievement of this goal, facilitated by coordinated efforts from various stakeholders all along the food value chains. This study focuses on examining the market dynamics of agricultural machinery trade in Bangladesh, Nepal, the Russian Federation, and Viet Nam by primarily looking at how markets are structured within each target country; the dynamics of demand and supply; insights into specific end-users' preferences; market segments within each country; current mechanization levels vis-à-vis demand; demand forecast in the near future; emerging mechanization trends in each country market, and how such a process can be driven sustainably.

The supply chain of agricultural machinery was found to be generally well-structured and established across markets of most countries. Stakeholders were playing their roles not only in taking mechanization technologies from producers to the end-users but also in helping identify future market preferences. The public sector support in acquiring mechanization technologies was, however, reckoned as instrumental in facilitating farming, manufacturing, and servicing communities in gearing up the mechanization process in all the countries reviewed.

Agricultural mechanization in Viet Nam, Bangladesh, and to some extent in Nepal has advanced to the second stage. Most farm operations such as tillage, seeding, irrigation water pumping, spraying, inter-row operation, grain harvesting & threshing, transport, milling require high to medium levels of power and low to medium levels of control and are largely mechanized. However, low levels of mechanization are observed in land leveling, paddy stand establishment, crop management and harvesting (especially in the non-paddy segment), horticulture, and value addition were observed as common in the three predominantly rice-producing countries except for mechanized paddy transplanting uptake in Viet Nam (65%). The Russian Federation has nearly reached the third or final stage of mechanization, with nearly all of the farming operations mechanized, including those requiring high levels of control and low levels of power such as transplanting, harvesting of sugarcane, cotton, fruits. Vegetable production remains substantially non-mechanized in the Russian Federation.

Most countries participating in the study did not indicate a significant lack of financing in both formal and informal sectors for the promotion of agricultural mechanization. However, some countries highlighted the necessity of allocating pre-determined financial outlays to support smallholders at discounted rates. One solution identified was land consolidation for crop production facilitated by appropriate policy instruments. This approach was suggested to not

only contribute to food security but also help reduce hunger and poverty in the rice-dominant countries. The experiences gained from the initiatives taken in Viet Nam and, to some extent, in Nepal have shown promising results in this regard.

All countries reviewed have incorporated agricultural mechanization in their national development frameworks, albeit at varying levels. This integration enables them to progress towards transforming their agricultural practices from the current high-input, high-output, low-efficiency, and unsustainable development model to one that is high-yield, high-quality, high-efficiency, ecosystem-friendly, and food-securing. Precision agriculture and smart farming avenues would prove even more attractive and rewarding opportunities, especially for the rural unemployed educated youth, including women, due to the potential for more productive and lucrative agricultural practices.

A summary of additional key recommendations from this research regarding public and private sector domains for enhancement of quality agricultural machinery manufacturing and trade in the national and regional markets of the countries studied includes the following:

a) Provision of:

- Creating and enabling environment for the development of agricultural mechanization entrepreneurship, especially by rural unemployed educated youth and women;
- Establishing Common Facility Center(s) in industrial hub(s) through public-private-partnerships with the agricultural machinery manufacturing industry for quality enhancement of local products and indigenization of imported machinery and components;
- Enhancing smart subsidies for the acquisition of agricultural machinery through purchase and custom hiring programs;
- Providing incentives such as;
    - Tax holidays to attract foreign direct investment (FDI) in establishing joint ventures (JVs) for quality machinery production,
    - Allowing duty-free import of agricultural machinery, including tractors and spare parts,
    - Offering rebates on the duty paid for the specialized but verifiable materials used in agricultural machinery manufacturing,

b) Reorientation of agricultural mechanization Research and Development (R&D) through:

- Implementing participatory product development involving technologists, manufacturers, and end-users for rapid commercialization,
- Utilizing ICT and satellite-based mechanization interventions, including robots and drones to promote precision agriculture and smart farming in the contexts of the changing climate and environmental impacts,
- Exploring and using renewable energy sources to promote sustainable agricultural mechanization,
- Integrating women in the development and efficient operation of agricultural mechanization technologies with emphasis on pulses and horticultural crop production and primary processing,

c) Capacity-building of stakeholders, including:

- Providing business management and technical

skills training to the agricultural light engineering industry;

- Assisting end-users, including custom hire servicing entrepreneurs, in developing business plans for efficient utilization of agricultural machinery, primarily through public support;
- Educating both sectors in the adoption of smart farming by utilizing intelligent ICT systems for marketing and accessing emerging agricultural technologies.

Private sector commitments include:

a) Upgrading product quality through:

- Integrating precision machinery with skilled human resources (HR);
- Leveraging the local auto-parts vending industry's strengths;
- Promoting active engagement between manufacturers and key stakeholders, including end-users, development practitioners, and academia.

b) Providing quality products and services through:

- Improving business management and marketing systems of the importers, distributors, and dealers;
- Building the capacity of end-users, mechanization services providers, and repairers in the efficient machinery management.

All public and private sector stakeholders of the agricultural machinery market chain should closely collaborate to enable the regional countries to fast-track their development efforts to achieve the Sustainable Development Goals. This collaboration should include adequate sourcing, disseminating information, and backstopping of socio-economic, agro-technological and environmentally sustainable mechanization technologies.

I. Introduction

A. Background

The Sustainable Development Goals[1] (SDGs) adopted by all 193 Members of the United Nations General Assembly in 2015, aim to promote prosperity while protecting the planet. They recognize that eliminating poverty must go together with development strategies that foster economic growth and address various social aspects, including health, education, social protection, and livelihood, as well as tackle climate change and environmental issues. These 17 SDGs serve as a roadmap to achieve a better and more sustainable future for all humanity.

An analytical review of the SDGs indicates that agriculture is among the most promising sectors of the economy for effectively contributing to the achievement of many of these goals in a sustainable manner. The 2021 United Nations Food Systems Summit also recognized that agriculture and food systems are key components in achieving global sustainable development[2]. In particular, the following SDGs share important linkages to agriculture in sustainable development: SDG #1(End poverty in all its forms everywhere), SDG #2(End hunger, achieve food security and improved nutrition and promote sustainable agriculture), SDG #5 (Achieve gender equality and empower all women and girls), SDG #6 (Ensure availability and sustainable management of water and sanitation for all), SDG #7(Ensure access to affordable, reliable, sustainable and modern energy for all), SDG #8 (Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all), SDG #12 (Ensure sustainable consumption and production patterns), SDG #13 (Take urgent action to combat climate change and its impacts), SDG #15 (Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss) and SDG #17 (Strengthen the means of implementation and revitalize the global partnership for sustainable development). Therefore, this study will base on aspects of the SDGs mentioned above.

A number of development issues including the degradation of the natural resource base, loss of biodiversity, and climate change pose challenges to the agriculture sector. These issues are being addressed globally, including in the Asia-Pacific region, primarily through the development and adoption of various biological, hydrological, chemical, and other technological interventions. However, the potential of mechanical technology remains sub-optimally tapped despite its ability to impact agriculture across a range of sub-sectors such as crops, natural resources use, and livestock, including aquaculture.

Agricultural mechanization is the application of mechanical technology and increased power to agriculture. It serves various purposes, including increasing labour and land productivity, expanding areas under cultivation, improving

farm profits and timeliness, reducing poverty and drudgery of agricultural operations; and enhancing food security through improved rural livelihoods. It includes the use of tractors, power tillers, animal- and human-powered implements and tools, as well as internal combustion engines, electric motors, solar power, and other energy conversion methods in food production systems. Mechanization also includes irrigation systems, food processing, and related technologies and equipment[3].

Over the past half century, the Asia-Pacific region has made significant progress in agricultural mechanization. In the 1960s the region was at the bottom of the global agricultural mechanization league. However, it has since progressed to become the region with the largest annual global sales of agricultural machinery[4].

In the 1960s, the debate on agricultural mechanization in the Asia-Pacific region was centered on the desirability, feasibility, and social consequences of replacing draft animals with internal combustion engines as a source of farm power. However, as per recent estimates, Asian countries will predominantly replace draft animals with tractors (single- or double-axle or a combination of both depending on specific country conditions), as well as diesel and/or electrical motors for powering irrigation pump-sets, harvesting machinery and equipment, and equipment for post-harvest handling and processing by the fourth decade of the present century. This transition represents a remarkable achievement that was difficult to imagine even at the turn of the twenty-first century.

A shift from traditional, labor-intensive crop production and post-harvest operations to mechanized, labor-saving technologies is taking place across the region's agriculture. This shift is driven by factors such as rising labor scarcity, and aging agricultural populations, increasing labor costs, and the increasing feminization of agriculture as more men than women migrate to urban areas. Additionally, the development of modern value chains is responding to increasing market development and trade opportunities within the region and globally[4].

The level of agricultural mechanization varies across countries in the Asia-Pacific region, with some nearing maturity level while others are in the middle and initial stages. The Information Communication Technologies (ICTs) have significant potential to help countries to catch up fast with the desired and sustainable levels of mechanization. This can be achieved by leveraging opportunities for agricultural machinery manufacturing, trading, and service provision through effective integration and networking in the region.

Given the different levels of economic development, landholding scales, cost of finance, gender dynamics, and other market forces, both machinery producers and consumers must consider appropriate mechanization solutions to suit local agro-technologic, socio-economic, environmental, and industrial conditions[3]. Understanding market dynamics, including consumer types, behavioral patterns, crops and cropping patterns, and existing levels of mechanization and gaps is essential. This ensures that farmers have access to appropriate

technology at competitive prices, and that the researchers and producers can effectively contribute towards these requirements.

In essence, suppliers of agricultural mechanization technologies should consider the design, economics, and socio-cultural aspects, adapting products to meet these differences. This approach ultimately contributes to sustainability. Similarly, it is necessary to identify the needs, aspirations, and challenges of smallholders and marginalized groups, including women farmers, as opportunities for niche market development in agricultural mechanization. Low affordability levels coupled with resource-poor financial conditions of these end-users have been considered significant obstacles to their development. Moreover, gender issues in agriculture are often overlooked as rural women are not adequately represented in agriculture policymaking. Despite a sizeable proportion of the agriculture workforce in many countries of the Asia-Pacific region being composed by women, the impact of mechanization on gender is not adequately addressed in development planning. Therefore, a thorough understanding of the existing and potential markets becomes of utmost significance also for such planning.

B. CSAM and ReCAMA

The Centre for Sustainable Agricultural Mechanization (CSAM), operates as a regional institution under the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP). CSAM's mandate is to achieve production gains, improve rural livelihoods, and alleviate poverty in Asia and the Pacific through sustainable agricultural mechanization practices, fostering a more resilient, inclusive, and sustainable agricultural sector.

One of CSAM's key initiatives is the Regional Council of Agricultural Machinery Associations (ReCAMA), established in October 2014, to engage the private sector in its mission. ReCAMA's mission is to promote sustainable agricultural mechanization in the region by strengthening the capacity of national agricultural machinery associations, facilitating the exchange of knowledge and information, and fostering collaboration and closer business relations among national associations and their members. ReCAMA is committed to facilitating research, trade, and investment in sustainable agricultural mechanization, thereby strengthening the linkages and networking among associations representing the manufacturers, distributors, and end-users of agricultural machinery across the region. ReCAMA has been closely collaborating with the member associations since its inception in fostering solid relationships and promoting trade and investment. With the support and technical guidance from CSAM, ReCAMA is promoting exchange of knowledge and information and strengthening collaboration and networking among national associations and their members. The member countries of ReCAMA are diverse in several ways, including the level of economic development, the extent of agriculture vis-à-vis its contribution to GDP, manufacturing capacity including the level of technology, research and development capabilities, government policy and the level of infrastructure development, particularly in relation

to agriculture. The intra-connectivity fostered by CSAM's through ReCAMA enables member associations to exchange information and provide mechanization technologies tailored to each country's needs. As of 2021, ReCAMA has 21 Member associations from 15 countries. The UN Office for South–South Cooperation recognized ReCAMA as a good practice in the third volume of its global publication titled 'Good Practices in South-South and Triangular Cooperation for Sustainable Development' in September 2020[5]. According to a 2020 survey conducted by CSAM, ReCAMA has encouraged or facilitated business opportunities worth around USD 30 million among its members through various activities since its inception.

II. Research Rationale, Objectives and Methodology

A. Present Research

At the 7th ReCAMA Members Meeting in 2021, the members endorsed a proposal to develop a research paper on market dynamics of agricultural mechanization in Bangladesh, Nepal, the Russian Federation, and Viet Nam. This is the second paper in a series focusing on market dynamics in selected countries, following the first research paper completed in 2020, which centered on China, India, Sri Lanka, and Thailand.[6] The research aims to explore strategies for ensuring the sustainability of this sector by contributing to the entire value chain and aligning with the Sustainable Development Goals.[7]

B. Research Rationale

The aim of this research is to understand the market dynamics of each target country concerning agricultural mechanization. This involves examining how markets are structured within each target country; understanding the dynamics of both demand and supply; gaining insights into specific end-user's preferences; identifying market segments within each country; evaluating the current level of mechanization and its alignment with demand; forecasting potential future demand; analyzing emerging trends towards mechanization in each country's market and exploring sustainable driving factors for this process. A cross-country research study therefore provides an opportunity for ReCAMA Members to understand the diverse market dynamics and potentially identify similarities. This will be useful not only for agricultural machinery manufacturing, marketing, distribution companies, and mechanization services provision entities, but also for policymakers in the target countries.

Access to information and knowledge is critical for members of the agricultural machinery associations to contribute effectively to promoting sustainable agriculture mechanization in their respective countries through informed decision-making. A comprehensive understanding of the market dynamics will benefit members in sourcing appropriate machinery for different segments. This, research will not only provide valuable insights into market dynamics but also help minimize marketing risks by selecting appropriate agricultural machinery for each segment. This, in turn, will boost regional growth in sustainable agricultural mechanization.

C. Research Scope

This research focuses on studying the national market status on agricultural mechanization in Bangladesh, Nepal, the Russian Federation, and Viet Nam. Its goal is to ensure sustainable development of agricultural mechanization

through the value chain, contributing to the relevant SDGs.

From an economic perspective, 'market' can be understood as a place, physical or virtual, where buyers and sellers come in contact with each other directly or indirectly to trade goods. It therefore encompasses the whole area of demand and supply operations, including the conditions and commercial relationships facilitating transactions. Each country is considered as a market by itself in this research. Market analysis is particularly beneficial for supply-side players. By analyzing the structure and dynamics of the market, this research can provide insights into the performance, competition, buyer behavior, current performance, future prospects, and develop marketing strategies that are responsive to the challenges presented by specific segments of the overall market. Furthermore, the outcome of this research will be also valuable for those on the demand-side, such as those entities seeking to buy agricultural machinery for self-use and/or provide mechanization services, as well as for those who wish to have access to information as to how the markets are functioning in countries where domestic agricultural production is predominant.[6] In addition, the research could benefit policy makers by providing evidence on whether the specific needs and requirements of smallholders, marginalized groups, and women farmers, are being met as supporting evidence for their future policy making.

D. Research Framework

The research framework was structured around the stages of application and by crop, which helped identify the degree of mechanization and existing gaps. For instance, the analysis of wheat could reveal the degree of mechanization at each application stage, such as land preparation, drilling, plant protection/management, harvest, and post-harvest. Additionally, the study analyzed the types of machinery used at each stage accounting for some other dimensions detailed in this study. By applying this framework to all major crops, the study provided a comprehensive understanding of market dynamics in the target countries.

E. Research Objectives

Since this research is the second in a series, the specific objectives were kept largely the same to ensure symmetry and comparability of results with the earlier study.[6] They included:

a) Assessing and analyzing the structure and dynamics of the agricultural machinery market in the respective application stages in Bangladesh, Nepal, Russian Federation, and Viet Nam;

b) Evaluating the current demand for agricultural machinery in the respective application stages, assessing the unmet demand and forecasting future trends, where applicable in each of the application stages;

c) Evaluating the extent to which the market addresses the need for economic, social, and environmental sustainability, considering the reality of climate change and identify gaps;

d) Comparing and contrasting the market dynamics for agricultural machinery in the target countries to understand the similarities or

differences.

e) Proposing recommendations for different stakeholders, including future research, training, and market awareness, on how the market can be leveraged to promote sustainable agricultural mechanization for the benefit of the target countries.

F. Research Methodology

For resource use optimization, this research has primarily utilized secondary data review and key stakeholder interviews to assess the current market status, evaluate future trends and identify gaps in agricultural mechanization while considering sustainability parameters. The secondary data review involved extensive data search across cross-referenced data sources, such as independent studies, government and regulatory publications, technical journals and trade magazines. The primary research involved interactions with key stakeholders including intermediaries, line departments, end-users, and support industries to gather qualitative insights.

To ensure standardization and comparability, the collected primary and secondary data were compiled, reported, and discussed for uniform reporting under the following headings for each target country:

- **Agricultural Profile, brief overview**
  - Overview of main crops grown and extents cultivated over the last five years.
- **Agricultural Mechanization**
  - Overview, machinery statistics over the last five years (domestic production, imports, and exports), annual production statistics (if applicable), trend analysis, mechanization status clustered by application stages for each cultivation stage and status by crop, gaps analysis in mechanization by application stages.
- **End-User Profile**
  - Categories of farmers and scale, approach to mechanization at present, and current unmet needs by application for crops.
- **Demand**
  - Determinants of demand, consistency of demand, and external interventions affecting demand.
- **Supply Chain**
  - Analysis and data collection of manufacturers, importers, together with national, regional, and local distribution and retail systems.
  - Understanding the constraints[8] faced by different individuals, companies, and organizations engaged in these activities.

  Sustainability Issues

  Assessment of how the market addresses economic, social, and environmental sustainability, identification of gaps, and recommendations for filling these gaps.

- **Conclusions and Recommendations**

  Drawing conclusions about successful areas of mechanization, met and unmet market needs, and specific areas needing attention from stakeholders to promote sustainable mechanization.

G. Research Paper Structure

Executive Summary highlights the significance,

lessons learned, and recommendations from the research.

Chapter 1 Provides a background information and introduce the research paper.

Chapter 2 Outlines the rationale, scope, framework, objectives, and methodology of the research.

Chapter 3 Presents the country market papers. With each country's agricultural profile, mechanization status, end-user profile, demand, supply chain, sustainability aspects, and conclusions and recommendations reported in a unified format.

Chapter 4 discusses the findings, compares the countries' markets and summarizes conclusions and recommendations for various stakeholders, including a future agenda for consideration of policymakers, ReCAMA Members, and CSAM.

III. Country Market Dynamics

A. Bangladesh Country Market

1) Agricultural profile, brief overview

Over the years, the relative significance of income and employment from agriculture has declined in most countries, including Bangladesh. In 1973-74, agriculture contributed 56.04 percent to the GDP, a figure that dropped to 13.48 percent by 2020-21. Despite this decrease in the sector's GDP share, its absolute contribution has increased almost six times. For instance, the average of agricultural GDP between 2005/6-2008/09 and 2014/15-2018/19, increased from Tk 96,700 crore to Tk 135,000 crore (a 40 percent increase) while the contribution to total GDP fell from around 18 percent to 14 percent (Asaduzzaman, 2021). Even more impressively, total food-grain production in Bangladesh has soared from 9.9 million metric tons in 1972 to 45.4 million tons in 2020. Bangladesh is the fourth largest rice and third largest freshwater fish producing country in the world (CRI, 2022).

Moreover, rice production has surged from 1.06 crore tons in 1982-83, to 3.76 crore tons in 2020-21, while potato production has jumped from 6.26 lakh tonnes in 1972-73 to about 0.98 crore tons in 2020-21. Similarly, maize production has increased from 3.0 thousand tons to 0.41 crore tons during the same period. The productivity of various crops has also seen a three to four times increase (Hossen, 2022), enabling the Bangladeshi Government to consider commercial agriculture. Table 3.1.1 illustrates the production of selected agricultural crops.

Table 3.1.1. Production of selected agricultural crops in a million MT (and million bales for jute)

Crops	Year					
	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21
Rice	34.71	33.80	36.28	36.39	36.60	37.61
Wheat	1.35	1.31	1.1	1.15	1.25	-
Potato	9.47	10.22	9.72	9.66	9.61	9.89
Oil seeds	0.93	0.97	1.03	0.95	0.97	0.99
Pulses	0.38	0.39	0.39	0.38	0.40	0.43
Maize	2.27	2.45	3.03	3.57	4.02	4.12
Vegetables	15.26	16.04	15.95	17.25	18.45	-
Jute* (in million bales)	7.55*	8.25*	8.89*	8.58*	8.05*	7.73*

Sources: 8th five-year plan of Bangladesh, BBS, 2021 and Yearbook of Agricultural Statistics, 2021

Agriculture is one of the most essential sectors in Bangladesh's economy. This area's activities focus on creating work opportunities, reducing poverty, improving human resources, food safety,

and so forth. GDP growth and contribution from different sectors are illustrated in Table 3.1.2.

Table 3.1.2. GDP growth and contribution of different sectors

Year	GDP Growth (%)	Agric to GDP (%)	GDP from Agric. (Million BDT)	Industry to GDP (%)	Services to GDP (%)	Net FDI (Million USD)
2016	7.10	14.05	9922.8	27.35	53.67	1285
2017	7.60	13.41	10117.3	27.75	53.48	1706
2018	7.86	13.07	10468.8	28.54	52.96	1583
2019	8.15	12.68	10799.1	29.65	52.85	2650
2020	3.51	12.92	11242.3	29.54	53.4	1510
2021	5.47	-	11540.5	-	-	1344

Note: GDP-Gross domestic product, FDI- Foreign Direct Investment.
Sources: Trading Economics, 2022, World Bank, 2022 and Statista, 2022

Crops in Bangladesh

Nine crops are considered major crops in Bangladesh: rice (73.94%), wheat (4.45%), jute (3.91%), rape and mustard (3.08%), lentil (1.54%), chickling vetch (1.25%), potato (1.13%), sugarcane (1.12%), and chilli (1.05%). These crops are grown on 1% or more cropland (14.61 million ha). The farming pattern of Bangladesh is dominated by rice. It has been widely categorized into three seasons: Aman, Boro, and Aus. Transplanted Aman occupies over 46.30 percent of the paddy area, followed by Boro (26.85 percent), Aus (17.59 percent), and broadcast Aman (9.26 percent). Wheat is the second most significant crop after rice. It is only sown as a winter crop and is grown chiefly in the drier northern regions of Bangladesh. While rated third in terms of area grown, jute is the top export crop in the country. It is mainly restricted to the low-lying regions of the Padma and Brahmaputra floodplains. The most significant and extensively cultivated winter vegetable is potato. It is the most significant crop in Munshiganj, Comilla, Rajshahi, Rangpur, Dinajpur, Bogra, Joypurhat, and Nilphamari districts. The 8th most important crop in the nation is sugarcane. The districts of Chuadanga, Natore, and Rajshahi are where it grows most. Cultivation of the chilli is primarily focused in the southern districts, particularly Bogra, Sirajganj, and Pabna (Bappy, 2017).

Gram (0.78%), millets and maize (0.60%), onion (0.58%), black gram (0.51%), sweet potato (0.45%), groundnut (0.40%), green pea (0.36%), sesame (0.33%), linseed (0.30%), garlic (0.20%), pea (0.12%), and barley (0.10%) are generally recognized as minor crops in Bangladesh. Additionally, some crops, such as vegetables and spices, occupy a negligible part of the gross-cropped area (GCA), or less than 0.10 percent for each crop, making up 1.57 percent of the total (Banglapedia, 2022). The second most popular crop for export is tea, a crop with a small area. The hills of the Maulvi Bazar district and a few isolated locations in the Habiganj, Sylhet, Chittagong, and Cox's Bazar districts are where it is primarily grown. Acreage and production of different crops in the last five years is presented in Table 3.1.3.

Table 3.1.3. Acreage and production of different crops 2015-2021

Acreage and production of crops		Year					
		2015-16	2016-17	2017-18	2018-19	2019-20	2020-21
Rice	Acreage M. ha	69.49	67.17	70.92	70.32	69.72	71.44
	Production '000' M. tons	34,710	33,804	36,278	36,391	36,604	37,608
Jute	Acreage M. ha	4.14	4.50	4.63	4.58	4.15	4.17
	Production '000' bales	7,554	8,247	8,895	8,576	8,045	7,725
Sugarcane	Acreage M. ha	0.60	0.56	0.55	0.51	0.53	0.95
	Production '000' M. tons	4,208	3,863	3,639	3,203	3,683	3,807
Tea	Acreage M. ha	0.37	0.33	0.33	0.33	0.36	0.34
	Production '000' M. tons	64.5	69.5	72.5	78.6	86.3	77.7
Pulses	Acreage M. ha	2.28	2.23	2.22	2.14	2.18	2.27
	Production '000' M. tons	378	387	390	378	398	425
Oilseeds	Acreage M. ha	2.78	2.96	2.77	2.69	2.92	3.05
	Production '000' M. tons	934	975	1,028	954	972	996
Maize	Acreage M. ha	1.99	2.04	2.38	2.72	2.88	2.93
	Production '000' M. tons	2,272	2,446	3,026	3,569	4,015	4,116
	Production '000' M. tons	378	388	394	378	397	425
Tobacco	Acreage M. ha	0.28	0.28	0.26	0.23	0.25	0.25
	Production '000' M. tons	88	88	89	82	86	89
Condiments and Spices	Acreage M. ha	2.44	2.52	2.49	2.46	2.58	2.62
	Production '000' M. tons	2,488	2,675	2,596	2,671	2,997	3,594
Potato	Acreage M. ha	2.90	3.05	2.91	2.86	2.82	2.86
	Production '000' M. tons	9,474	10,216	9,725	9,655	9,606	9,887

Sources: BBS, 2021 and Source: Yearbook of Agricultural Statistics-2021

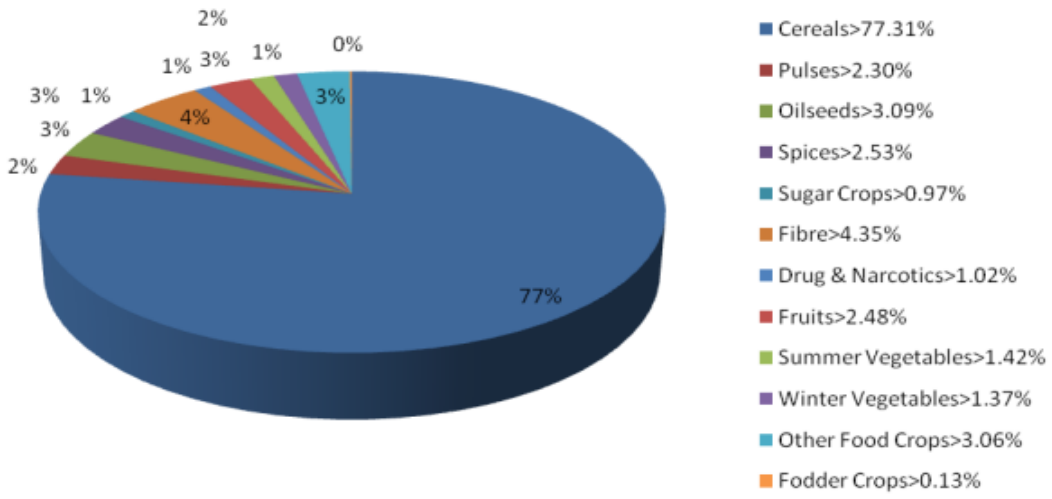


Figure 3.1.1: Area under cultivation of different crops in Bangladesh, 2020-21

Source: Yearbook of Agricultural Statistics, 2021

2) Agricultural Mechanization

(i) Brief overview

Mechanization is the process of changing from working exclusively by hand or with animals to doing that work with machinery and farm mechanization, which refers to the development and use of machines that take the place of human and animal power in agricultural processes. It streamlines and lightens labor-intensive tasks, makes up for workforce shortages, boosts productivity, and may help mitigate problems related to climate change (Negrete, 2019). In Bangladesh, deep tube wells (DTW) for irrigation were first used in the early 1960s, when agricultural mechanization began (Pingali, 2007). Bangladesh's irrigation policy underwent a significant transformation following its independence in 1971, with the promotion of shallow tube wells (STWs) and low lift pumps (LLPs) (Biggs and Justice, 2015). In 1988, removing import taxes on various agricultural equipment (Biggs and Justice, 2013), particularly diesel engines and two-wheeled tractors (2WTs) marked the beginning of a greater mechanized process in Bangladesh. Due to this regulatory change (Kienzle et al. 2013), imports of small engines and machinery, mostly from China, have surged (Mottaleb et al. 2016). As a result, agricultural machinery prices decreased (Gisselquist et al. 2002), and their sales dramatically increased. Six years later, 2WT (two-wheel tractor) imports were duty-free (Anon 2012.), attracting private sector participation. Local agro-machinery manufacturing workshops were established nationwide in the 1990s (Alam et al. 2017). As a result, the agricultural machinery demand in the country has risen steadily (Islam, 2018). The National Agricultural Policy of 1999 witnessed a further expansion of this sector through tax incentives and credit facilities, as many of these workshops were gradually evolving into small-scale industries (Hossen, 2019).

The market for agricultural machinery has steadily grown over time, with a notable emphasis

on product quality. However, this growth has brought challenges, as some local business owners have developed low-quality machinery to offer farmers cheaper options, resulting in negative effects. Consequently, the industry is now faced with the pressing need to maintain precision in production processes. Despite these challenges, Bangladesh's early adoption of agricultural mechanization was made more accessible by focusing on small-scale equipment that could be adapted to the country's socio-economic environment.

Imported machinery and local spare parts production were linked to the second stage of expansion. Farm mechanization in Bangladesh is currently in its third phase, resulting from numerous public and commercial initiatives supported by the "National Agricultural Mechanization Policy" developed in 2020 (MoA. 2020).

Bangladesh has made strides recently as a developing country, which may be attributed to the ongoing expansion of agriculture. Despite outstanding performance metrics, the agricultural productivity of the country is still quite low. The scientific community agrees that farm mechanization can help the agricultural growth in the future by assuring timely operations and reducing associated costs. In order to lessen the negative consequences of climate change, of which Bangladesh is a primary victim, this is especially crucial. During challenging periods like the COVID-19 pandemic and the current geopolitical tensions, the importance of farm mechanization has been keenly felt by many. For instance, since the onset of the pandemic, there has been a rapid adoption of paddy combine harvesters in various regions. This adoption has been crucial in protecting millions of hectares of mature rice fields from the immediate threat of early floods. These efforts have been supported under the development of assistance programmes, highlighting the critical role of mechanization in safeguarding agricultural productivity during crises. Similar activities in the other agricultural fields, such as precision farming, spraying, and transplanting, may also increase overall agricultural productivity.

(ii) Machinery statistics (Imports / Exports / Domestic production) for the last 5 years

There is no complete or current census of the various farm machinery utilized in Bangladesh. As a result, the data collection for this study (Table 3.1.4) was based on the most recent annual reports and surveys released by various ministries, organizations, and sales records of importers, reports of newspapers, and key producers of farm machinery in the country that reflected the pre-pandemic environment. In terms of quantity, diesel engines emerged as the farmers' preferred energy source. Diesel engines are utilized for various agricultural tasks, though they are primarily employed to power irrigation pumps. For instance, rural transportation of agricultural commodities heavily relies on small, locally produced boats and trolleys powered by diesel engines.

Power tillers (2WTs), which are also powered by diesel engines, come in first place on the list of tillage machinery (745,000 units), as indicated in Table 3.1.4. The 2WTs are less expensive than four-wheel tractors and simpler to move about in

the fields. Additionally, 2WT's repairs and maintenance are now expertly performed by nationwide neighborhood specialists, which motivates farmers to purchase these machines. Currently, 2WTs are used to cultivate around 80% of the nation's land, while tractors are used in the remaining 18% (Table 3.1.5).

Table 3.1.4. Present status of agricultural machinery

Operations	**Farm Machinery**	**Quantity (Nos.)**	**Sources**
Tillage	Power Tiller	745,000	MoA, 2021
	Tractor	158,000	
	Rotary Tiller	7,000	
Weeding	Weeder	250,500	Kabir, 2019
Seeding	Power Operated seeder	5,000	Rahman et al., 2021
Spraying	Knapsack Sprayer	2,000,000	Kabir, 2019
Transplanting	Rice Transplanter	>1,000	Hossen, 2020
Fertilizer application	USG Application	1,600	Rahman et al., 2021
	Prilled urea applicator	18,000	
Harvesting	Combine Harvester	9,000	Hossen, 2022
	Reaper	1,434	MoA, 2021
Threshing	Thresher	390,000	Kabir, 2019
	Maize Sheller	23,500	BARI, 2017
Winnowing	Winnower	3,000	MoA, 2021
Irrigation	Low Lift Pump	204,391	BADC, 2022
	Deep Tube Well	36,955	BADC, 2022
	Shallow Tube Well	1,490,689	BADC, 2022
	Solar pump	>300	Rahman et al., 2021
Power source	Diesel Engine	3,700,000	Kabir, 2019
Drying	Mechanical dryer	>600	

A total of 1.57 million Low-lift Pumps (LLPs), Shallow Tube Wells (STWs), and Deep Tube Wells (DTWs) (BADC, 2019) are also operated to irrigate nearly 98% of all cropland (Table 3.1.5). Pesticide and herbicide spray in the country has also been mechanized over 95%.

Table 3.1.5. Percent (%) of agricultural mechanization based on field operations

Operation	Methods	% of mechanization	Sources
Land preparation	Tillage implements (2-WT and 4-WT, leveler, different type of ploughs, tillage equipment, harrows, etc.)	98	Hossen, 2019, Hossen, 2020 and Rahman et al., 2021
	Cattle/traditional	2	
Transplanting	Machine transplanting (transplanting machines, sowing machines)	5	
	Human labor/conventional	95	
Weeding	Engine power and human power operated equipment (power weeders, manual weeders)	8	
	Manual	92	
Fertilizer	Machine operated (manual and power operated applicators)	5	
	Human labor/conventional	95	
Irrigation	LLP, DTW and STW	98	
	Traditional	2	
Pesticide/Herbicide application	Mechanical	95	
	Manual	5	
Reaping	Self-operated, power tiller operated and modern combined (Power-take-off (PTO) reapers, self-propelled reapers, combine harvesters, strippers, stripper headers)	12	Hossen, 2022
	Conventional (sickle)	88	
Threshing (paddy)	Machine operated	97	Hossen, 2019 and Hossen, 2020
	Conventional	3	
Post-harvest	Mechanical (dryer)	5	
	Manual	95	
Storage	Modern	15	Hossen, 2019
	Traditional	85	
Processing (rice)	Mechanical (De-husker, Whitener, Separator, Polisher)	100	Inspira, 2019
	Traditional	0	

Source: Hossen, 2019, Hossen, 2020, Rahman et al., 2021, Hossen, 2022 and Inspira, 2019

Although there have been notable success stories, the adoption of other agricultural machinery such as bed makers, seeders, weeders, rice transplanters, and winnowers remains sluggish. However, there has been an interesting development in the case of transplanting and harvesting machines. To encourage timely planting and harvesting of paddy and wheat

before the start of the monsoon, the government has been providing subsidies for 15 categories of different agricultural machinery and giving more emphasis to transplanting and harvesting machines since 2016. Under these activities, Department of Agricultural Extension (DAE) is now implementing a project titled 'Farm Mechanization through Integrated Management' from 2020 to 2025 (Table 3.1.6). The government has prioritized mechanization due to severe labour scarcity to meet planting deadlines and harvest crops before any natural disasters occur at the start of the rainy season. This subsidy programme creates momentum for mechanization in Bangladesh.

On the other hand, some governmental and private banks came forward to contribute to this sector along with governmental initiatives. Presently, Bangladesh Krishi Bank, Rajshahi Krishi Unnayon Bank, Islami Bank, Pubali Bank, Dutch Bangla Bank, Bank Asia, Social Islami Bank, NCC Bank, and others, are giving soft loans at the rate of 9% interest to the machinery importers. In comparison, it is 6% for the machinery manufacturers. On the contrary, farmers purchased machinery at the interest rate of 10 to 11% for 2 to 3 years.

Table 3.1.6. Categories and number of the machinery under the development assistance programme

Sl no.	Name	Number	Comments
1	Combine harvester for paddy and wheat (Whole feed and head feed)	15,000	Mainly imported
2	Combine harvester for maize	500	Imported
3	Rice and wheat reaper	4,000	Mainly imported
4	Rice and wheat Reaper Binder	2,000	Imported
5	Rice transplanter (riding type)	1,000	Imported
	Rice transplanter (walking type)	2,000	Imported
6	Seeder/Bed planter	5,000	Local and imported
7	Power thresher for paddy and wheat	5,000	Local
8	Maize Sheller	5,000	Local
9	Dryer	5,000	Local and imported
10	Power sprayer	2,000	Local and imported
11	Power weeder	500	Local and imported
12	Potato digger	3,000	Local and imported
13	Potato chips maker	1,000	Local and imported
14	Carrot washer	300	Local
15	Spare parts	-	Local and imported

Source: DAE, 2022

(iii) Trend analysis

Farm power is a crucial component of agricultural production. Completing different farm activities in time depends on available power, including the

operation of irrigation equipment, tillers, weeders, threshers, shellers, cleaners, graders, and other post-harvest machinery. One of the most important metrics for assessing the level of mechanization in agriculture is the amount of power available. The average power availability in agriculture has improved in Bangladesh over the past 58 years, rising from roughly 0.24 kW/ha in 1960 to approximately 2.3 kW/ha in 2020 (Fig. 3.1.2). From 1960-1990, farm power increased slowly, and then it increased sharply. It is still increasing due to governmental subsidy programs and development activities of other research and non-government organizations.

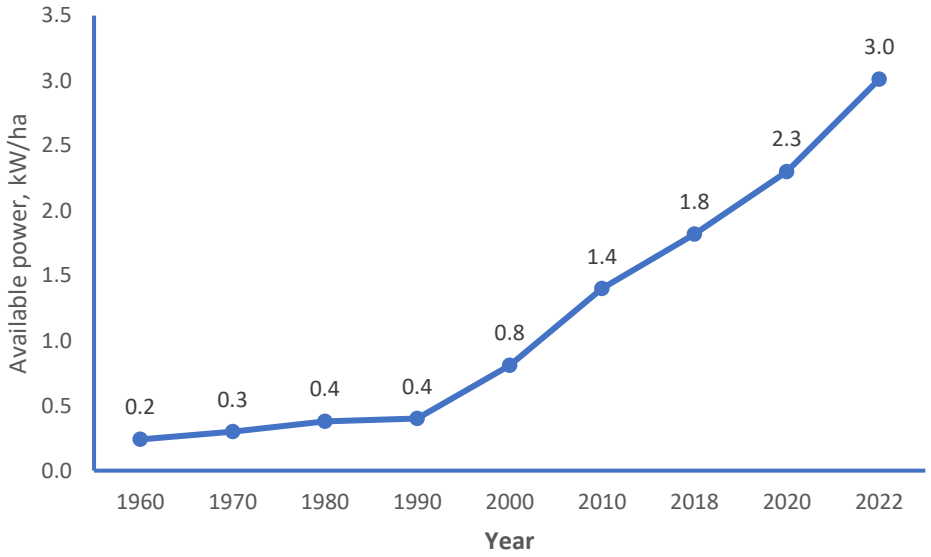


Figure 3.1.2. Available farm power in agriculture over the period

Source: Hossen, 2019, Hossen, 2020 and Rahman et al., 2021

Tillage: Power tillers (PT), rotavators, tractors, and hydro tillers are used for tillage. Among them, power tillers and four-wheel tractors are mostly used for tillage. Current sales trends indicate that PT sales are declining due to increased sales of tractors for agricultural purposes. Moreover, the creation of a business environment by importing firms, local service providers (LSPs), and commission agents, as well as agricultural machinery subsidy programs by the government, have contributed and are keeping agricultural mechanization development at a rapid pace. Remarkably, almost complete mechanization (98%) has been achieved in land cultivation in Bangladesh. At present, about 745,000 Power Tillers (PT)/two-wheel tractors, 158,000 four-wheel tractors, and more than 7,000 high-speed rotary tractors are used in agriculture in the country. Power tiller import trends increased rapidly (60,000 to 62,000) between 2004 and 2007 but increased slightly until 2011, then again declined in 2013 due to policy changes. In 2014-2016, PT market started to grow, but in 2017-2018, due to the growth of the tractor market, PT market started to decrease again. Four-wheel tractors are being used in the eastern (Comilla and adjoining districts), southwestern (Jesore), and northern (Dinajpur and adjoining districts) regions of the country.

Irrigation: The government is giving importance to increasing the use of surface water for

sustainable water use and proper management of water resources. It has implemented many initiatives, including excavation and re-excavation of rivers and canals, construction of rubber dams, reservoirs, and use of water-saving methods. The cost of irrigation in crop production has already come down significantly, and initiatives are continuing to reduce it further. Future plans for irrigation modernization include 60 lakh hectares of irrigated area at public and private levels by 2030, increasing irrigation efficiency from 38% to 50%, increasing surface water use in irrigation to 30% and reducing groundwater use by 70%. As a result of the agriculture-friendly policies of the present government, the irrigated area has expanded by 10.50 lakh hectares in the last ten years, and the current total irrigated area is 56.27 lakh hectares. It has been possible to increase irrigation efficiency from 35% to 38% and surface water utilization from 21% to 27%. As a result of various measures, 73% of irrigable land has come under irrigation. Currently, there are 36,955 deep tubewells, 1,490,689 shallow tubewells, 204,391 low-lift pumps, and more than 300 solar pumps in Bangladesh (Table 3.1.4). Deep tube boils are being used in some areas as an alternative to centrifugal pumps as the water level falls. As a result, the low lift pump use has decreased slightly. About 888 Axial Flow Pumps (AFP) are used in Bangladesh, where the water level is very low (southern region) and can supply more water than centrifugal pumps used for irrigation. AFPs are becoming popular in the southern districts of the country. Moreover, 9,457 km of irrigation canals have been re-excavated in the last ten years; 13,351 km of irrigation canals have been laid, and ten rubber dams and one hydraulic elevator dam have been constructed.

Transplanting: Bangladesh is still far behind in the use of machinery in transplanting. At present, under the "Agricultural Mechanization through Integrated Management" project, which is being conducted under the Directorate of Agricultural Extension, the programme of providing planting machinery to the farmers directly under the subsidy of 50% in plain areas and 70% in Hawar and coastal areas has been started. About 1,000 rice transplanters were supplied in the past through various programmes and projects at subsidized prices among farmers. Precision rice transplanters are becoming more prevalent among Bangladeshi farmers. The leading causes of the machine's delayed uptake are the challenges of growing mat type seedling and the dearth of skilled operators during the busiest transplanting season. Under the ongoing support of the subsidy program, prompt adoption of precision rice transplanters is required to reduce the labor involved in seedling rearing and transplanting. In addition, nationwide training programs for the development of skilled operators should be maintained. Under the subsidy program, a well-known rice transplanter model (both walking and riding type rice transplanter imported from Japan, Republic of Korea, China, and India) was selected for use by farmers.

Intercultural operation: Inter-management of rice generally refers to weed control. In recent times, herbicides have been used extensively to control weeds. This pollutes the environment and harms pests and fish farming in open water bodies. Currently, about 250,500 weeders and 2,000,000 sprayers are being used in the field (Table 3.1.4). Although about 8 percent of weeding is

mechanized, 92 percent of the land is still weeded by hand (Table 3.1.5). BARI agricultural weeders, Bangladesh Rice Research Institute (BRRI) weeders, BRRI powered weeders are being used at the field level. Women workers can use the weeding machine very easily. Farmers presently are inclining to the multirow power weeder to avoid drudgery. Pesticides are sprayed using various sprayers, and 95 percent of spraying involves using machines.

Harvesting: Harvesting is still done with traditional sickles, and the productivity is extremely low (about 0.01 ha/hour/worker). Due to labor shortages and natural calamities, sometimes entire crops are lost. As a result of providing subsidized combine harvesters at the farmer level, more than 3,000 machines are operating at the field level, and the farmers have been able to harvest paddy smoothly in the Boro season 2020-2021. If this trend continues, it is believed that there will be an unprecedented success in the mechanization of rice harvesting in the next few years. Hence, the government has placed particular emphasis on the mechanization of paddy harvesting. Already in several areas of the country, including haor, there has been an expected improvement in the mechanization of paddy harvesting. Currently, a project - "Agriculture Mechanization through Integrated Management" is being conducted under the Directorate of Agricultural Extension. The project is to provide combine harvesters to the farmers directly at 50% subsidy in plain areas, and 70% subsidy in haor and coastal areas. A total of 15,000 combine harvesters will be provided to farmers under the project. During the last Boro season (2021-22), around 6,000 combine harvesters were supplied to farmers. More than 9,000 combine harvesters are being successfully used at the farmer level in the country, with horsepower ranges from 50 to 120.

Threshing and winnowing: Proper threshing and winnowing at the right time is a crucial task among the various activities of paddy production. Out of the average 10% loss from harvesting to drying in a conventional method, the loss in mechanized rice threshing is 3.16%. By popularizing combine harvesters at the farmer level, threshing and threshing losses can be reduced. At present, about 97% of paddy is threshed using threshers and 6% paddy is cleaned using winnowers. However, 390,000 paddy threshers and 23,500 maize shellers are being used successfully in Bangladesh (Table 3.1.4).

Drying: Sun drying of paddy is a common method applied in Bangladesh which is entirely dependent on weather. As a result of climate change, adverse weather conditions and unpredictable rains have resulted in loss of rice quality due to wetting or delayed drying. Recirculating dryers are used in auto rice mills to deal with this problem. Also semi-auto rice mills and Angeberg Haller rice millers are used to dry the paddy under the sun. Furthermore, about 600 BAU-STR dryers and 100 BRRI seed dryers are being used at the farmer level with the help of the Department of Agricultural Extension (DAE). Besides these, development and research work on batch dryers, cellar dryers, cabinet dryers, and flatbed dryers are ongoing at Bangladesh Rice Research Institute.

Milling: Over-milling in husking mills increases

the amount of broken rice and reduces the quality of rice. Due to this, milling recovery is less than 2-4 percent compared to auto mills. In addition, the husking mill produces pulp, husk, bran, and chaff together, which cannot be used for other purposes, including oil production. This wastage can be reduced by 1-2% by gradually converting from Engelberg huller to rubber-roll huller. The rice produced by automatic and semi-automatic rice mills is fine, stone and black rice free, and transparent. Moreover, the by-products of these mills are being used in the production of manure-oil, bran-briquettes, and poultry/cattle farms. The resulting denatured/black rice is used in feed mills to prepare fish and livestock feed. There are about 19,000 rice mills in the country, including 500 automatic rice mills, 700 semi-automatic rice mills, and 17,500 husking mills. Two-thirds of the total rice produced in Bangladesh is processed through automatic and semi-automatic mills, and the remaining one-third is processed through husking (Engelberg Husker) mills.

(iv) Agricultural machinery market size, importers and manufacturers

There are approximately 75 importers in the nation, of which 20 import tractors and rotavators from China and India. Only nine of the 20 importers, including Metal, ACI, Abedin, Alim, Uttaran, SQ Agril machinery, AADI enterprise, Bangla Mark, EoN Machinery, primarily import rice transplanters, combine harvesters, and reapers from China, Japan, Republic of Korea, Viet Nam, and India. ACI, Abedin, and The Metal share the combine harvester market at the percentage of 31, 30, and 29 percent respectively, while other companies share only 10 percent of the total market. Additionally, about 65 of 75 importers, import various types of small agricultural machinery, including power tillers, diesel engines, pumps, knapsack sprayers, and spare parts. While sprayers (power or knapsack) and irrigation pumps are imported from China, Republic of Korea, and India, nearly all power tillers (model names Dongfeng and Sifang) are imported solely from China and used extensively in Bangladesh. Sprayers have now been manufactured locally, and many pumps are manufactured in Bangladesh. In Bangladesh, the overall market performance over a year for agricultural machinery is estimated to be worth USD1.28 billion in 2019 (Table 3.1.7). In 2022, approximately 1,300 combine harvesters and 934 reapers were provided. Nonetheless, USD 42.73 million in expenses were incurred for the timely paddy harvesting in the absence of laborers in the rural area. At present, about 9,000 combine harvesters are being used at the field level due to a government subsidy programme, and the market size has increased by about 4 to 5 times from the 2019 market size.

In addition to machinery imports, the nation currently has about 70 foundries, 800 agricultural machinery manufacturing facilities, 1,500 spare parts manufacturing facilities, and about 20,000 repair and maintenance facilities operating in producing and servicing agricultural equipment and spare parts (Islam, 2018). A small number of agro-machinery workshops are also working in Bangladesh, including Alim Industries Limited in Sylhet, Rahman Engineering Workshop in Kushtia, Mahboob Engineering in Jamalpur, Comilla Cooperative Karkhana in Comilla, Janata Engineering in Chuadanga, Uttaran Engineering

Workshop in Dinajpur, MAWTS in Dhaka, The Metal Private limited in Gazipur, ACI in Manikgonj, Advanced agro machinery in Kishoreganj, Anser Energy Ltd. in Jamalpure, Bhai Bhai Engineering in Netrokona, and others. Similar to these manufacturers, several small producers have been set up throughout the nation to produce items like threshers, winnowers, weeders, applicators, solar light traps, irrigation pumps, knapsack sprayers, threshers, seeders, maize shellers, rice milling equipment, and spare parts for engines and power tillers to meet local demand through close cooperation with the research institutions.

Table 3.1.7. Approximate market size (in million USD) of agricultural machinery in 2019

Agricultural Machinery	**Qty**	**Average Unit Price, USD**	**Total, Million USD**
Power Tillers	45,000	1,562.50	70.31
Tractor	8,000	15,000.00	120.00
Rotary Tiller	3,000	2,500.00	7.50
Combine Harvester	1,200	31,250.00	40.63
Reaper	600	2,250.00	2.10
Transplanter	100	5,000.00	0.50
Pump	750,000	187.50	140.63
Engine	1,200,000	250.00	300.00
Thresher	20,000	562.50	11.25
Seeder	100	937.50	0.094
Weeder	500	2.50	0.001
Sprayer	700,000	18.75	13.13
Maize sheller	7,000	625.00	4.38
Total Farm Machinery Market Price *(including with Imported and Local)*			710.50
R & M Cost *(around 5 -7 % on total value for the first year)*			35.53
Existing Machinery Repair and Maintenance Cost *(around 15% on the total value of sold machinery in the last 5 years)*			532.88
Agricultural Machinery Market Size in Bangladesh			**1,278.92**

Source: Alim Industries Ltd., Sylhet, Bangladesh

(v) Agricultural Machinery Spare Parts Market

By focusing on scale-appropriate farm mechanization, locally produced spare parts can significantly impact the nation's economy. Typically, agricultural machinery spare parts (such as power tillers, tractors, combine harvesters, transplanters, engines, pumps, etc.) are imported from countries such as China, Republic of Korea, Japan, Viet Nam, and India, and also locally produced in Bogura, Sylhet, Natore, Jashore, Dhaka, and other parts of the nation. In 2011, Bangladesh's projected spare parts market was worth roughly USD 325 million, of which USD 250 million was produced locally (Alam et al., 2017). However, in 2019, the size of the total spare parts market was approximately USD 369

million, of which the local portion was approximately USD 295 million (Fig. 3.1.2). This indicates that the country uses fewer imported replacement parts as a result of the considerable changes in the supply chain of readily available spare parts in Bangladesh each year (Alam et al., 2017). In addition to making significant foreign currency savings, this practice reduces reliance on imported replacement parts. Bogura City is now gaining popularity as Bangladesh's largest industrial hub for agri-machinery and its replacement parts. About 80% of machines and parts, including irrigation pumps, threshers, maize shellers, pistons, and liners, are produced, with the remaining 20% coming from Dhaka and the Jashore district. However, Bogura and other parts of Bangladesh lack the necessary infrastructure to produce agricultural machinery, and the sub-sector that makes its spare parts.

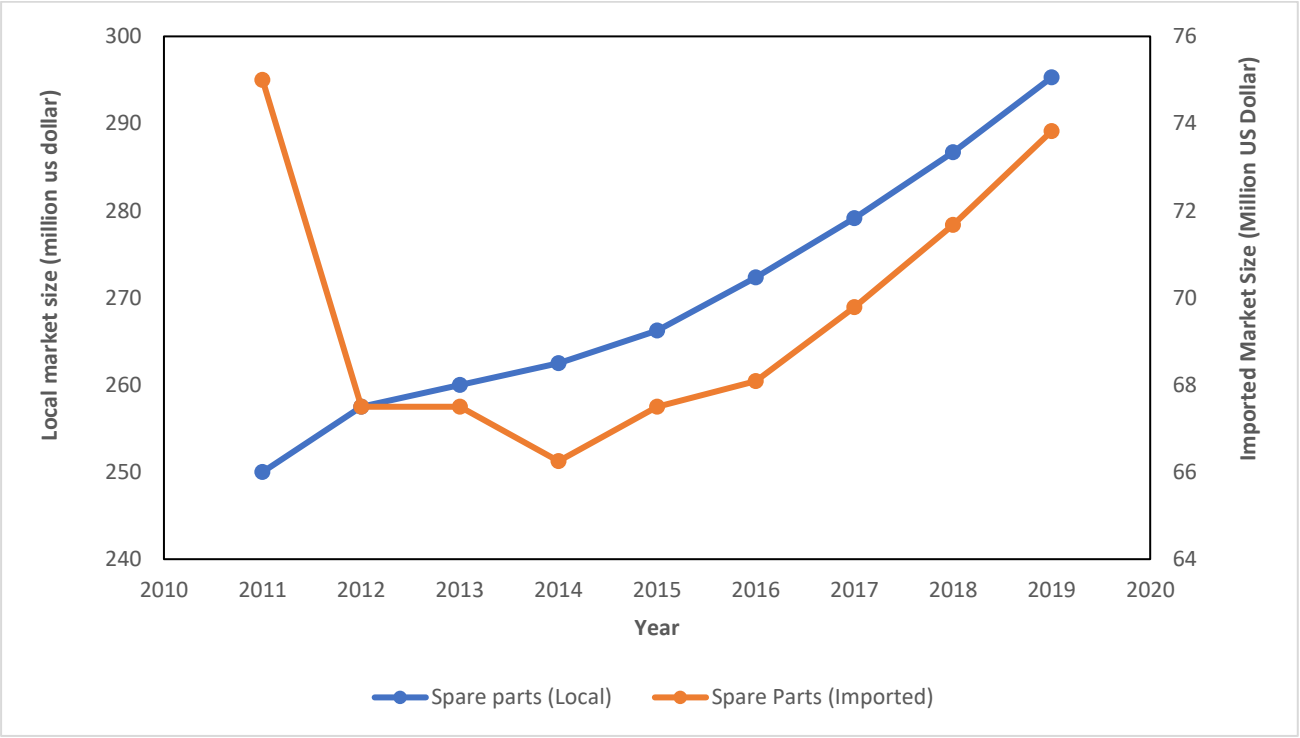


Figure 3.1.3. Approximate annual market size of spare parts in Bangladesh (Anisur et al., 2020)

(vii) Gaps in mechanization

The gap of mechanization by application stages of the different crops is shown in Table 3.1.8. Tillage, irrigation, threshing, and milling mechanization levels are remarkably satisfactory in Bangladesh. There is much scope in planting, intercultural operation, harvesting, and processing different crops. Rice mechanization is significantly high compared to the other crops. Fruits and vegetable mechanization is still low in Bangladesh.

Table 3.1.8: Mechanization Clustered of the major crops by Application Stages

Major Crops	Cultivation Stages				
	Land preparation	Seeding / Planting	Crop Management	Harvesting / Threshing	Post - Harvesting
Paddy	Tractors, Power tillers, Plough, Disk harrow, Cultivator Rotavator	PTO seeder Transplanter (Limited scale)	Weeder Sprayers Water pumps Solar Pumps	Reapers, Thresher Winnowers Combine harvester	Dryer (Limited scale) and de-husker
Wheat	Tractors, Power tillers, Plough, Disk harrow Cultivator	Seed drill PTO seeder VMP	Sprayers Water pumps Solar Pumps	Reapers, Thresher Winnowers Combine	Wheat flour mill
Maize	Tractors, Power tillers, Plough, Disk harrow Cultivator	Seed Planter Seed drill PTO seeder VMP (Limited scale)	Sprayers Water pumps Power weeder	De-huskers Shellers Threshers	None
Lentils	Tractors, Power tillers, Plough, Disk harrow Cultivator	PTO seeder VMP	Sprayers Water pumps	None	None
Oil seeds	Tractors, Power tillers, Plough, Disk harrow Cultivator	None	Sprayers Water pumps	none	None
Sugarcane	Tractors, Plough, Disk harrow Cultivator Rotavator	Mechanical planter (limited scale)	Water pumps Sprayers	None	None
Potato	Tractors, Power tillers, Plough, Disk harrow, Cultivator Rotavator	Potato planter (Limited scale)	Sprayers Water pumps Solar Pumps	Potato digger	Potato grader
Vegetables	Tractors, Power tillers, Mini tiller, Plough, Disk harrow, Cultivator	None	Sprayers Water pumps Solar Pumps Micro irrigation	None	None
Fruits	Tractors, Power tillers, Plough, Cultivator	None	Sprayers Water pumps Micro irrigation drip irrigation	None	Solar drying (Limited Scale)

Source: BRRI, Bangladesh, 2022

3) End-User Profile

(i) Land Utilization Statistics

Land Utilization Statistics of Bangladesh are given in Table 3.1.9. The total cropped area has increased due to irrigation facilities and agricultural modernization.

Table 3.1.9. Land Utilization Statistics of Bangladesh

Item	Area in thousand ha			
	2016-17	2017-18	2018-19	2019-20
Not available for cultivation	21,950.35	21,846.57	20,667.88	20,470.19
Forest area	15,735.66	15,735.66	15,723.30	15,723.30
Cultivable waste area	1,420.85	1,420.85	1,579.00	1,658.08
Current fallow area	2,456.23	2,241.24	2,782.40	2,634.14
Total cropped area	94,532.55	95,224.45	97,253.18	98,046.39

Source: Bangladesh Statistics, 2020 and BBS, 2021

(ii) Number of households

The number of households in Bangladesh from 2013 to 2021 increased gradually. The total number of households in 2013 was 32.2 million, whereas 35.2 million in 2021 (Statista, 2022).

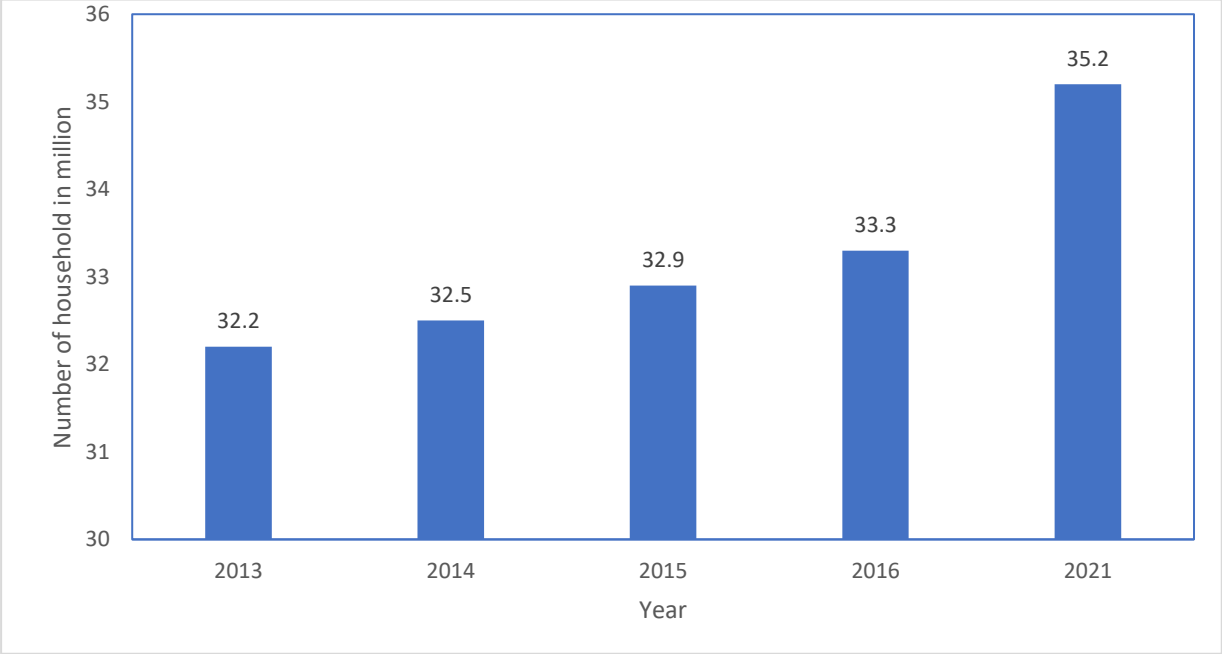


Figure 3.1.4. Number of households in Bangladesh

(iii) Distribution of households

The preliminary findings available from the agricultural census 2019 show that there are 35,533,180 households (dwelling households) in total in the country, of which 29,624,975 (83.37%) are in rural areas and only 5,908,205 (16.63%) are in urban areas (Table 3.1.10).

Table 3.1.10. Household statistics of Bangladesh according to the Agricultural Census 2019

Sl. No.	Items	National	Urban	Rural
1	Dwelling household	35,533,180	5,908,205	29,624,975
2	Fisheries household	995,135	31,087	964,048
3	Agricultural labor household	9,095,977	121,631	8,974,346
4	Household having no own land	4,024,189	1,700,919	2,323,270
5	Tenant household	6,763,487	229,245	6,534,242
6	Dwelling household	16,562,974	617,855	15,945,119
7	Dwelling household	1,605,185	53,005	1,552,180

(iv) Number of holdings and farm size

The number of holdings and farm sizes of different agricultural censuses of Bangladesh is presented in Table 3.1.11. The number of holdings, both of farm and non-farm, increased while the percentage of farm holdings in comparison with the total holdings decreased over time. Agriculture is still a reliable source of employment for 42.7 percent of the workforce. Due to the scarcity of land, the number of marginal small class farmers is increasing. They are now the only reliable source of food security in the country that survive by gripping only a piece of land. Sustainable agricultural production and poverty alleviation will be ensured if proper technology is introduced on their farms.

Table 3.1.11. Number of holdings and farm size of different agricultural censuses of Bangladesh

(Rural area only)

Sl. No.	Item	1983-84	1996	2008	2018
1	Number of holdings				
1.1	Total	13,817,646	17,828,187	25,351,506	27,480,054
1.2	Non-farm	3,772,347	6,029,945	10,480,930	10,137,392
1.3	Farm	10,045,299	11,798,242	14,870,576	17,342,662
2	Percent of holdings (%)				
2.1	Total farm holdings	72.7	66.18	58.66	63.10999971
2.2	Small farm (0.02 – 1.00 ha)	70.34	79.87	84.27	0
2.3	Medium farm (1.01 – 3.03 ha)	24.72	17.61	14.19	0
2.4	Large farm (3.04 ha and above)	8.67	10.18	9.58	0
3	Operated area (ha)				
3.1	All holdings	9,315,825	8,289,815	9,285,211	8,896,635
3.2	Per holdings	0.67	0.46	0.37	0.32
3.3	Farm holding	9,177,657	8,076,377	8,881,029	5,755,033
3.4	Per farm holdings	0.91	0.68	0.60	0.33
4	Household area (ha)				
4.1	All holdings	390,921	533,544.1	807,632.7	0

Sl. No.	Item	1983-84	1996	2008	2018
4.2	Per holding	0.028	0.028	0.032	0
4.3	Per non-farm holding	0.016	0.020	0.024	0
4.4	Per farm holding	0.032	0.036	0.036	0
5	Cultivated area (ha)				
5.1	All farm holding	8,157,484	7,191,812	761,4321	0
5.2	Per farm holding	0.81	0.61	0.51	0
5.3	Temporary-crops net area	7,711,413	6,657,298	7,058,968	0
5.4	Temporary-crops net area per farm	0.79	0.56	0.47	0

Source: Report on Agriculture and Rural Statistics 2018

(v) Current Unmet Needs

Paddy, maize, and wheat threshing mechanization significantly progressed along with irrigation and rice milling mechanization. But still Bangladesh lags far behind in transplanting, harvesting, and drying mechanization. Mechanization in planting, intercultural operation, harvesting, and processing other cereals and pules, vegetables, and fruits is of utmost need. Despite the early introduction of rice transplanters in the country, the majority of rice transplanting is still done manually. Due to the unique technological requirements of rice transplanters of mat type seedling raising and high initial costs, adoption is relatively delayed. There still seems to be an unfulfilled mechanization potential in the areas mentioned above.

Demand for mechanical rice transplanting and harvesting services is now driven by rising labor costs and supply constraints, particularly during the peak period of rice transplanting and harvesting season. The government has responded by offering subsidies on the sale price of various machines, including combine harvesters and rice transplanters as well as dryers, seeders, potato diggers, power weeders, maize harvesters, etc. The private sector has responded by aggressively marketing and selling rice transplanters and combine harvesters. Despite this, the uptake of combine harvesters and rice transplanters has lagged behind expectations, and many aspects of crop production are still carried out by hand. Another unmet need appears to be developing and expanding of effective sowing and harvesting equipment for small grain pulses and cereal crops. Except for the transportation and land preparation, all other operations related to sugarcane production in Bangladesh have not been mechanized. Sugarcane planting and harvesting mechanization has not yet begun because of the high initial cost. Although conservation farming and minimum tillage techniques have been used for some time in Bangladesh, farmers are nonetheless unenthusiastic about them. This approach still seems unrealized mechanization because conservation Agriculture practice is still at an evaluation stage for rice (the predominant crop) by different research institutions and universities. Conservation agriculture is mostly suitable for high value crops and is being practiced for non-

rice crops such as pulses and vegetables. Other than these, the constraints include the increasing availability and affordability of inputs for conservation cultivations (herbicide and mechanization), the distribution of household workload and gender issues, farmer risk-taking behavior, problems with land tenure, inconsistencies in policy, a lack of qualified extension services, and aspects of the traditional mindset. Cleaning, grading, and drying technologies for crop grains, fruit, potatoes, and vegetables are also scarcely mechanized in Bangladesh for post-harvesting operations.

4) Demand

Farm mechanization is currently underway with a difference of governmental and non-governmental initiatives. Diesel engines, power tillers, and other small equipment were in high demand among the small-scale and even large-scale farmers prior to the 1990s because they required less capital cost than tractors, combine harvesters, and rice transplanters. Following the development and implementation of several government programmes providing agricultural machinery subsidies to farmers, both small- and large-scale farmers were encouraged to purchase the machines in line with their needs. Power tillers, mini tillers, reapers, and threshers quickly gained popularity thanks to public and private support due to the quick payoff of initial capital costs. Nowadays tractors, power tillers, harvesters/reapers, transplanters, dryers, and other agricultural equipment are commonly used in rural areas, which helps farmers save time and operation costs. The majority of farmers in the country are small or marginal farmers. Tractors, rice transplanters, paddy and maize harvesters, potato planters, mechanical dryers, etc. are all beyond their means. The government took the initiative in 2021 to provide farmers with 56,000 pieces of agricultural equipment as part of a USD 31.98 billion programme by 2025. Farmers are acquiring 15 categories of agricultural machinery through the programme at 70% subsidy in the Haor and coastal areas and 50% subsidy in other places. This project has created momentum in agricultural mechanization. Approximately 6,000 combine harvesters have already been distributed to farmers, and 9,000 harvesters with 50 to 120 horsepower are operating successfully in Bangladesh. According to this proposal, farmers will receive a total of 15,000 combine harvesters, compared to the country's estimated 50,000 overall needs. Combine harvesters continue to be in high demand. Due to the critical labor shortage, the short time between crops, aptitude, fighting against natural disasters, etc., farmers are now highly motivated to use machinery in various agricultural operations, most notably planting, harvesting, intercultural operations, drying and processing of rice along with wheat, maize, potato, sugarcane, etc.

Consistency of demand

Presently, market demand for combine harvesters, rice transplanters, paddy and maize threshers, paddy and fruits dryers, seeders, bed planters, maize harvesters, potato diggers, carrot washers, wet and dry land power weeders, is fully guided by the government subsidy programme and about 56,000 pieces of 15 categories machinery will be supplied to the end users. Many 2WTs, 4WTs, threshers, diesel engines, irrigation

pumps, and plowing equipment are also purchased beyond this program. The entire annual demand for the listed machinery under the programme for mechanization is heavily influenced by the subsidy support. Despite the government and non-government activities, there is an almost annual constant market demand of about 20-25 thousand of paddy threshers, 35-40 thousand of 2WTs, 10-12 thousand of 4WTs, 40-50 thousand of diesel engine, 70-80 thousand of irrigation pumps and 15-20 thousand of hand-operated maize shellers. Before 2010, there was annual market demand of 70-80 thousand of 2WTs. The demand for 2WTs is declining with time but the market need of 4WTs has been almost the same since 2010. Soon, the market of 4WTs might be increased for its multi-function across the year. The market of combine harvesters and rice transplanters is fully guided by the governmental subsidy program. After completion of the program, an annual 4-5 thousand combine harvesters might be created due to the dependency of the end-users, labor crisis, and high cost of labor.

Usually, the consistency of the market demand depends on the type and purpose of the machinery; for example, tractors, tillage implements, diesel engines, and trolleys are in constant demand because of their various applications. The need for machinery in rural areas usually is dependent upon the rice and other crops seasons. In Bangladesh, different crops are grown round the year in different seasons. Hence, a common demand for agricultural machinery is almost constant. During harvesting Aus, Aman, and Boro rice in July-August, December-January, and April-May, respectively, the demand for harvesters, threshers and dryers increases significantly. The changes of bank interest rates, fuel and electricity price, and other factors cyclically impact demand for mechanization.

5) Supply Chain

Figure 3.1.5 illustrates a flow diagram of the agricultural machinery and spare parts supply chain in Bangladesh from manufacturers to end users. Most of the machinery like combine harvesters, reapers, rice transplanters, 2WTs, 4WTs, tillage implements, intercultural tools, irrigation pumps, etc. are generally imported from other countries, while threshers, weeders, winnowers, potato diggers and planters, maize shellers, dryers, etc. are manufactured locally. However, tools and implements of de-huskers, shellers, threshers, trolleys, and certain hand tools are produced locally. Moreover, parts of the locally manufactured machinery and even 2WTs and 4WTs are manufactured locally, while the essential parts are imported from abroad. Majority of the machinery is imported from China and India, with a small number of specialized machines coming from Republic of Korea, Japan, Viet Nam, Germany, UK, and Türkiye.

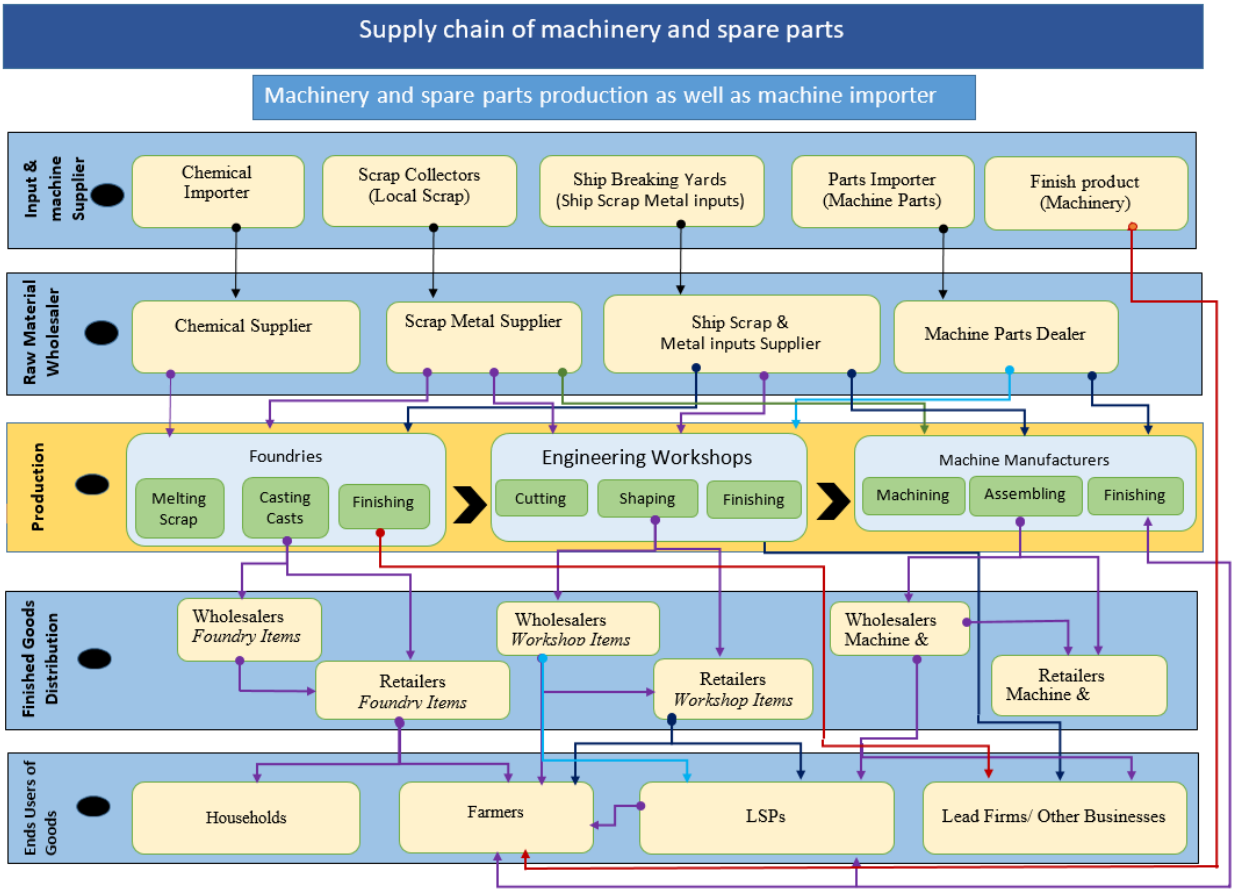


Fig.3.1.5. Supply chain of the agricultural machinery and spare parts (imported and manufactured)

6) Sustainability

When advancing the food and agricultural industries through sustainable mechanization, many factors need to be taken into account to ensure the sustainability of mechanization along with technological, economic, social, and environmental ones, including the following issues:

(i) Small size and scattered land holding, financial inability of the small and marginal farmers, lack of technical knowledge and lack of repair and replacement facility of the spare parts at the farmers' level.

(ii) Lack of skilled and experienced workforce, qualified manpower, modern capital machinery, quality and graded materials, foundries and spare parts, and high price of raw materials at the manufacturer level.

(iii) Insufficient modern facilities, inadequate knowledge and training, weak linkage and coordination, weak machinery extension service, insufficient information, and no certification at the institutional level.

(iv) Naturally formed infrastructure, no access roads, and unplanned irrigation system.

(v) Geographical characteristics such as soil type, soil bearing capacity, and hill/low land, etc.

A wide range of additional causes and limitations affect the promotion of mechanization levels. Factors include: developing and implementing

appropriate policies and procedures, taxation (import charges, industrial tax) and/or subsidies based on the significance of the technology, endeavors in research and development, research facilities and targeted extension services expanding agricultural engineering across the nation, specialized services fostering entrepreneurship (encouraging farmers' access credit through flexible hiring/leasing), equipment service providers, accessible spare parts, and effective interactions among stakeholders. Manufacturing of agricultural machinery has numerous challenges despite being a promising subsector, which includes:

- Almost everywhere in manufacturing, repair & maintenance, and sales after services, there is a shortage of competent and experienced workers.
- Poorly made products with substandard materials.
- Pig iron, shipbreaking scraps, and local scrap iron, steel, brass, etc. are the only raw materials used in the construction of foundries, pumps, and replacement parts. Due to increased global competition, particularly from China and India, the availability of old ships for the shipbreaking industry has declined in recent years.
- Compared to manufacturing imported agricultural machinery and spare parts, domestic production of agricultural machinery and spare parts is severely threatened by the high cost and lack of availability of raw materials.

Conservation agriculture (CA) based on different tillage technology is gaining popularity in the upland of direct seeding areas (Northern part of Bangladesh) also through the moderate level of crop residue. CIMMYT introduced this technology in farmers' fields of Bangladesh for wheat crops in collaboration with Wheat Research Centre, Bangladesh Agricultural Research Institute (BARI). Farmers accept CA-based tillage technologies considering the advantages of higher yield, reduced cost of tillage operation, and minimum turnaround time between the crops. Mostly CA practice is getting popularity for non-rice crops in Bangladesh. On the other hand, rice straw is mainly used for dairy feed; hence, farmers collect all straw in Aman (non-irrigated wet season) while major porting allows them to decompose in the field. Newly imported combine harvesters have the technology to slash and spread the machine-ejected straw during paddy harvesting. In time, these combines are gaining popularity in the country.

When advancing the food and agricultural industries through sustainable mechanization, many factors need to be taken into account, including technological, economic, social, and environmental aspects. Ensuring the sustainability of mechanization involves addressing issues such as small land holdings, financial constraints of small farmers, lack of technical knowledge, and inadequate repair and replacement facilities for spare parts at the farmers' level. At the manufacturer level, challenges include a lack of skilled and experienced workforce, lack of modern capital machinery, and high prices of raw materials. Insufficient modern facilities, inadequate knowledge and training, weak linkage and coordination, and a lack of machinery extension services and information at the institutional level also need to be overcome. Furthermore,

geographical characteristics such as soil type, soil bearing capacity, and terrain play a crucial role in sustainable mechanization efforts.

To make agricultural mechanization sustainable and satisfying for future needs, multiple directions must be taken. Training, equipment demonstrations, financial assistance for high-quality machinery, the creation and execution of short-, medium- and long-term strategic plans, the development of research and development capabilities, strong ties among various stakeholders, the promotion of technology-based production industries and the distribution of machinery appropriate for the soil, crops, and cultures of different regions are all ways to promote sustainable farm mechanization.

7) Conclusions and Recommendations

(i). Way forward for sustainable mechanization

- Agricultural mechanization is one of the key factors driving Bangladesh's transformation from subsistence to semi-commercial agriculture. The Government top objective is to ensure sustainable production to reduce poverty and hunger levels through mechanization of agriculture.
- In order to coordinate agricultural mechanization initiatives, appropriate guidelines, advisory committee, and cooperative efforts between public and private sector actors are required.

(ii). Availability of quality spare parts

- A lack of availability of quality spare parts during field operations often prevents the potential use of the technology.
- Supporting local manufacturers through awareness-improvement training to develop and produce cutting-edge agricultural machinery and spare parts is necessary under the National Agricultural Mechanization Policy 2020 and Mechanization Road Map.
- Initiatives should be taken to improve the quality of locally manufactured spare parts.
- Fast-moving spare parts of the imported machinery should be appropriately identified for indigenization.

(iii). Skill training and Repair and maintenance

- Training programmes are required to improve the skills of employees and managers of machinery and spare parts workshops to ensure product quality.
- To ensure that agricultural machines and spare parts are manufactured with high quality, trainings are required in factory layout, spare parts and machine design, and developing and reading drawings.
- Building capacity of personnel in marketing and financial management is required, as well as in skills for repairing and maintenance.
- Access to information about markets, export potential, current capital equipment, and better manufacturing technology options is necessary for producers.
- Local foundries must be upgraded through cooperation and knowledge exchange with industrialized nations and the South Asian Association for Regional Cooperation (SAARC).
- Capital equipment is required, as is training on how to operate it efficiently. Financial services companies or investors equities need to fund these investments often.

(iv). Entrepreneurship and technology adoption

- Bangladeshi farmers lack the resources to purchase equipment, even with the help of a subsidy scheme. However, the nation has entrepreneurs who can use the subsidies to buy machines and provide services to the community.
- Mechanization promotion programmes like the National Agricultural Mechanization Policy 2020 and providing 50% to 70% machine purchase subsidy would not be sufficient. To speed up the adoption of new agricultural mechanized technology, public-private partnerships policy should be defined and promoted. Banking credit rules, trade policies, quality regulations, and the provision of extension services must be addressed.
- Infrastructure (approach roads, field access) must be modified to allow larger machines, like combine harvesters, to access all Bangladeshi farmland.
- A change in government policy is required to allow companies to test and use drones to apply fertilizer and pesticides.
- A registration system for combine harvesters and other similar machines should be established. Additionally, GPS trackers should be installed on combines, rice transplanters, and tractors.

(v). Access to finance

- Access to financing is a common issue for all stakeholders involved in the agriculture industry.
- Systems for loan repayment must be created to take into consideration the sector's seasonality. In order to be ready for clients to purchase in advance, agricultural machinery and spare parts must be built before the cropping seasons because they are mostly purchased and used during those times.
- Foreign investment is required for the light engineering industry, which could develop as a significant part of the Bangladeshi economy. Incentives to facilitate investment in Bangladesh and, more crucially, the repatriation of this capital are needed to encourage this.

(vi). Female and youth entrepreneurs

The primary driving force in the light engineering and agricultural machinery service provision industries would be rural, educated women and youth. In order to encourage them to become rural-based entrepreneurs in the agricultural mechanization industry, business skills training, financial support, and incentives shall be put in place.

(vii). Crosscutting aspects

- Parallel to the import of machinery, emphasis should be placed on R&D for indigenous manufacturing.
- Constructing manufacturing facilities or assembly lines for specific technology, such as rice transplanters and combine harvesters is necessary.
- Continued training, incentives, and demonstrations on high-quality equipment are required.
- Timely provision and availability of spare parts for imported machines needs to be targeted through manufacture within the country.
- It is vital to create and spread technologies specific to a given location and soil type.

- Tax exemptions on spare parts are necessary to boost local production.
- The university, the research organizations, and the extension departments should collaborate closely and productively to meet the current market requirements.
- From the 100 economic zones that have been declared, a sizable number should be created to include agro-processing technology industries.
- It is also vital to determine the current situation and any prospective future requirements before designating the priority of various agricultural machines for multiple crops in each sub-region.

B. Nepal Country Market

1) Agricultural profile, brief overview

Nepal is a mountainous country having wide range of altitudes and ecological zones within a total area of 147,181 sq. km. Out of the total area, only 21 percent (3.09 million ha) is arable.[9] The country is primarily divided into three agro-ecological zones namely Terai, Mid hill, and High mountains (Figure 3.2.1). The Terai region is basically an extension of the Indo-Gangetic plain and consists of fertile lowlands. The Mid hill and High Mountain regions consist of undulating and steep topography with small valleys in between. With the variation of altitudes, Nepal experiences a wide range of climates and provides both opportunities and challenges for agricultural production.

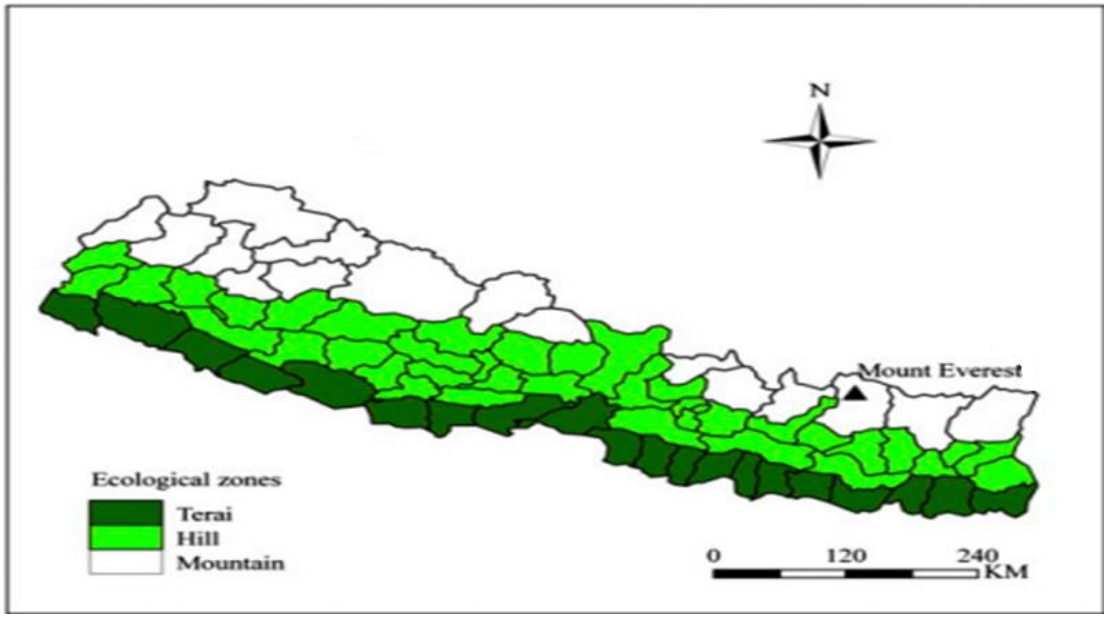


Figure 3.2.1: Map showing three ecological zones of Nepal

Source: LI-BIRD, Nepal

Nepal is largely an agrarian country, with agriculture being one of the major sectors of the national economy in income, employment, and food security. The agricultural sector alone contributes 27.7% to the GDP, providing employment to 60.4% of the population.[10] Besides food security, agriculture is also important for supplying raw materials to the industry and tradable items for foreign exchange. Nepalese agriculture is dominated by smallholdings and subsistence farming, resulting in the lowest levels of cereal productivity among the South Asian countries.[11] Rice, maize, and wheat are the three major cereal crops grown in most parts of the country, which jointly contribute about 30.54 % of Agricultural GDP of the country.[12] Millet, barley, pulses, oilseeds, potatoes, sugarcane, fruits, and vegetables are important crops in Nepal. The production area of major cereals and cash crops and their yields are represented in Tables 3.2.1 & 3.2.2, respectively.

Table 3.2.1. Major Cereal Crops Grown by Area and Yield, (2015/16 – 2019/20)

Year	Paddy		Maize		Wheat	
	Area (ha)	Yield (Mt/ha)	Area (ha)	Yield (Mt/ha)	Area (ha)	Yield (Mt/ha)
2015/16	1,362,908	3.15	891,583	2.5	745,823	2.33
2016/17	1,552,469	3.37	900,288	2.55	735,850	2.55
2017/18	1,469,545	3.51	954,158	2.68	706,843	2.76
2018/19	1,491,744	3.76	956,447	2.84	703,992	2.85
2019/20	1,458,915	3.80	957,650	2.96	707,505	3.09

Source: MoALD (2020)

Table 3.2.2. Major Cash Crops Grown by Area and Yield, (2015/16 – 2019/20)

Year	Oilseeds		Potato		Sugarcane	
	Area (ha)	Yield (Mt/ha)	Area (ha)	Yield (Mt/ha)	Area (ha)	Yield (Mt/ha)
2015/16	217,867	0.78	199,971	14.03	80,931	53.71
2016/17	207,978	0.78	185,879	13.94	70,807	45.47
2017/18	224,595	0.78	195,268	15.81	78,609	46.81
2018/19	260,307	1.08	193,997	16.05	71,625	49.67
2019/20	258,141	1.08	188,098	16.65	68,565	49.59

Source: MoALD (2020)

Rice, as a primary staple crop of Nepal, is grown on almost 1.5 million hectares and the national average productivity is a little over 3.5 tons per hectare. Traditionally, rice is a monsoon crop in Nepal and is mainly cultivated in June/July and harvested in October/November. With the growing irrigation facilities and the government promotional initiatives, spring season rice (February/March - June/July) has also been cultivated on 8 to 10 percent of the total rice production area. The productivity of spring rice is higher (4.4 ton/ha) than the monsoon rice in Nepal. Maize cultivation is a way of life for most farmers in the hills of Nepal. It is a traditional crop cultivated as food, feed, and fodder on sloping land (rainfed upland). The maize cultivation area has been increasing gradually since the growing demand of feed industries in the last few years. Wheat is Nepal's third most important crop in terms of cultivated area and total production.

The cereal yields in Nepal are low compared to the neighboring countries, although they are increasing. The country's self-sufficiency in food grain production has not been achieved as the growth of supply could not keep pace with the increasing demand for food. In 2021, the total cereal production in Nepal was estimated as 10.3 million tons. For the 2021/22 marketing year (July/June), cereal import requirements were forecast at 2.3 million tons.[13] The variation of area under a particular crop cultivation and its productivity are generally influenced by the rainfall pattern, seasonal climatic variations, and market price of the produce. The government of Nepal has started fixing the minimum support price of a few main crops (rice, wheat, and sugarcane) before the harvesting season. This is an appealing price policy taken by the government in favor of farmers to ensure the market for the

farmers' produce and protect the cultivator farmers against price slumping during the harvest season. This kind of price-fixing policy from the government has started increasing the farmers' confidence in farming business.

2) Overview of Agricultural Mechanization

Mechanization levels in Nepal were relatively low until a few decades ago. However, significant mechanization growth, including the adoption of tractors, has occurred since the 1990s against rising rural wages.[14] In Nepal, the major efforts for mechanization were often made for a confined area of Terai plains. Mechanization in the hills has remained challenging due to topography challenges, fragmented land, small and terraced plots.[15] Mechanization in the hills started only after 2010, when Chinese small horsepower tractors (mini-tillers) were introduced into the Nepalese market.[16] In 2014, the government of Nepal introduced a new Agricultural Mechanization Promotion Policy (AMPP), aiming to promote scale-appropriate and geography-specific mechanization. Although agricultural mechanization has a long-established history in Nepal, starting with the introduction of two- and four-wheeled tractors in the 1970s,[17] this promulgation of mechanization policy provided an opportunity for both the public and private sectors to invest in and expand farmers' access to agricultural machinery.

The most common forms of farm mechanization adopted in Nepal are the large and small tractors for tillage, mechanical seeding, threshing, and harvesting. After the tractors, threshers and small- scale irrigation pumps are the most popular farm machines in most parts of the country. Tractors are widely used in tillage and transportation of agricultural products and PTO-driven threshers are common in the threshing of wheat and rice. By the 2000s, nearly all wheat in the Terai was threshed with power threshers. Rice threshers came later, and by 2015 about 75% of all rice in the Terai was threshed with power rice threshers.[18] Reapers and combine harvesters are also gaining popularity for harvesting rice and wheat. A current estimate suggests that over 12,000 reapers and 750 combine harvesters are being used on a custom hiring basis in most Terai districts. In recent years, with the increasing road connectivity, the use of tractors, power tillers, pump-sets, and threshers has also increased in rural hills and mountains.[15] By 2018, over 10,000 mini-tillers were used in the mid-hills of Nepal.[19] A recent estimate suggests that the mini tillers' population has doubled on hill farms. These all indicate that the agricultural mechanization level of the country has been shifting in a positive direction since the last few years. In addition, mechanical interventions are being increasingly used in the rapidly growing horticultural, poultry, dairy, and animal feed industries and other value-added chains, mainly through private sector initiatives.[15]

3) Machinery Statistics (Imports / Exports / Domestic production)

Data on agricultural mechanization, such as demand, domestic supply and import, is very scanty in Nepal, and hence challenging to obtain comprehensive statistical information at the national level. However, some annual import data

of agricultural machines according to HS code during 2017-2021 is presented in Table 3.2.3.

Table 3.2.3. Imports of Agricultural Machinery in 2017 – 2021

Machinery Imported	Number of machines imported annually					Source country
	2017	2018	2019	2020	2021	
Tractors (both 4WT & 2WT)	17,085	13,396	15,411	52,210	58,385	China, India
Harrow, Rotavator, Cultivator, Weeders & Hoes	221,150	261,842	278,902	328,118	297,410	China, India, Republic of Korea
Plough & Disk harrow	23,541	32,091	85,772	176,352	269,568	China, India
Seeder, planter, Transplanter	2,763	1,214	1,436	4,951	3,157	China, India Japan
Threshers / Shellers	21,933	25,948	20,719	8,439	14,896	China, India, New Zealand
Reapers	2,450	1,562	1,927	1,859	4,170	China, India Japan
Combine harvester	-	75	110	156	168	China, India
Baler & Haymaking machine	1,356	1,004	2,107	1,883	4,029	China, India
Water pumps	57,930	57,829	32,400	41,082	74,855	China, India

Source: DOC (2017-2021) & DOTM (2019)

4) Domestic Production Status

Nepalese farmers have been using various agricultural machines for long; however, the domestic production status of machines is very poor in Nepal. Domestic production is limited to local manufacturing of small hand tools and iron ploughs. Some local metal workshops are manufacturing weeders, threshers, and tractor trolleys to meet the local demand. This small-scale production of farm tools and equipment is irregular and rarely gets an entry in national statistics.

5) Trend Analysis:

Tractors and Power tillers: The tractor has always been the hero of agricultural mechanization and rural transportation in Nepal. During the initial days, Nepal used to import tractors (2WT & 4WT) and pump sets from Japan and the Republic of Korea. But since the late 1980s, almost all 4-wheel tractors are imported from India and 2-wheel tractors from China. Both tractors are very popular for wetland, stationary, and haulage work. In recent years, the import of low horse-power 2WT (also known as mini tiller) from China is significantly high. The farmers in the mid hills found the mini tillers (5 to 9 hp size) are an appropriate technology for their small holdings, so there has been a rapid growth of its market in the last few years. The multiple use feature of the tractor keeps it in great demand in the Nepalese market.

Ploughs, Harrows, Rotavators, and Cultivators: With the growing number of tractors, the demand for land tillage and soil preparation implements is also rising (Figure 3.2.2). A significant growth is seen in the demand for rotavators, cultivator, and

disk harrows, which are the most popular implements for land preparation for all types of crops. Every new tractor purchaser wishes to have a rotavator and disk harrow as this increases the owner's opportunity to hire out the tractor.

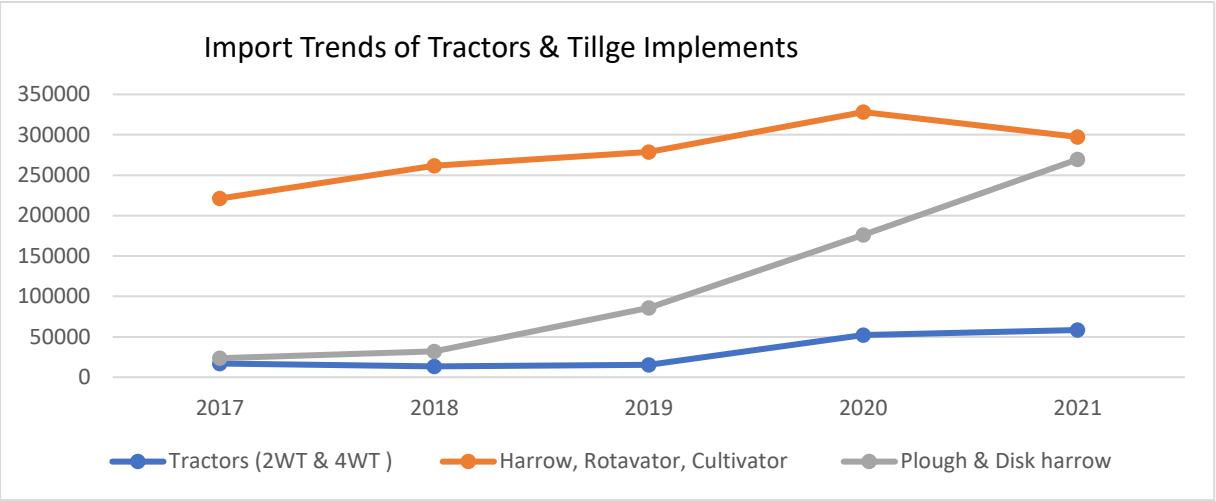


Figure 3.2.2. Import Trends of Tractors and Tillage Implements in Nepal

Seeders, Planters, and Transplanters: Farmers are also gradually showing interest in seeding and planting machines. Minimum till seed drill and planter machines are being promoted for resource conservation farming. However, rice is the main crop of Nepal and is grown in most areas; the adoption rate of rice transplanters is slow as most farmers find it complex and expensive.

Harvesting Machines: As a small-scale harvesting machine, the reaper is gaining popularity in Terai and inner valleys. Self-propelled and tractors mounted reapers are popular in Nepal. The annual demand for reapers was around 1,800 before 2020, and the trend increased significantly in 2021 with a yearly demand for reapers over 4,000 units. The adoption of combine harvesters in Nepal does not have a long history, the first combine harvesters was registered in 2000. Since the early 2020s, more than 750 combine harvesters are in operation in the Terai region. Each year on an average 75 combine harvesters were imported during 2017-2021, with an increasing import trend.[20] Most of the combines are imported from India, and farmers use them to harvest paddy and wheat on a custom hiring basis. Along with the combines, imports of balers and hay-making machines have also increased in recent years.

Threshing Machines: The annual import data of threshers indicates a decline in momentum and denotes for a saturated market stage. The market is supplying the new threshers mostly for the old users to suit their scale and the new farmers in hills are also adopting them, constituting a small portion of the market. In some districts, the dealers are also offering the exchange of old threshers with new ones. The farmers are finding this offer an opportunity to replace their old units with the latest ones. Since the combine harvesters have already been introduced in most of the Terai districts and are growing annually,

this may hamper the total demand for threshers in the future. At the same time, demand for small power threshers and motorized maize shellers is rising in hilly districts with the increased market accessibility and electrification facilities in rural areas.

6) Import Values of Machines

Table 3.2.4. Value of Annual Import of Selected Agricultural Machines

Machinery Imported	* Import value of machines (1000, USD)			
	2018	**2019**	**2020**	**2021**
Tractors (both 4WT & 2WT)	8,809.40	8,020.20	8,816.50	13,538.0
Harrow, Rotavator, Cultivator	8,052.20	7,649.80	4,938.30	8,098.0
Plough & Disk harrow	654.80	789.68	828.85	1,501.85
Seeder, Planter, Transplanter	240.30	137.78	63.62	328.80
Threshers/Shellers	4,267.38	5,912.85	5,895.53	9,812.70
Reapers	441.70	890.90	872.00	1,059.90
Combine harvester	1,926.40	2,759.80	3,793.70	4,270.40
Balers & Hey Making Machines	267.64	924.50	886.80	1,202.43
Water Pumps	6,237.76	6,198.37	5,614.05	9,281.32
Sprayers & Dryers	5,282.00	1,750.98	4,540.85	5,600.80
Dairy & Milking Machines	2,619.50	1,843.40	1,902.43	1,435.65
Total	**38,802.28**	**36,848.36**	**38,152.63**	**56,129.85**

Source: DOC (2017-2021)

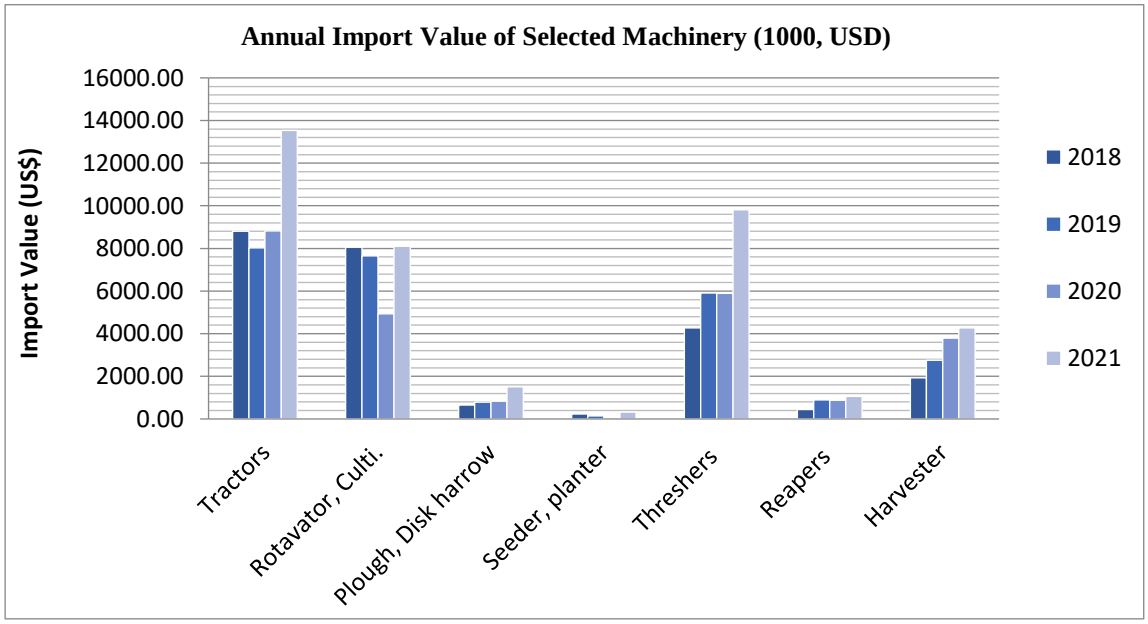


Figure 3.2.3. Annual Import Value of Selected Machinery

Note: The import values of selected machinery are adopted by converting Nepalese currency NRs to USD with the respective annual exchange rates (Source: DOC, 2018-2021).

The annual import values remained the highest for tractors, followed by tractor operated

machinery (tillage implements and threshers). The import values for tractors and threshers remained significantly increased for the year 2021 because of higher demands of 2WT and small-scale threshers in the hilly region. Investment values for seeders and planters constantly remained the least, indicating the low priority of mechanization in crop seeding and planting. Above all, the investment value on reapers and combine harvesters has shown an increasing trend in recent years, indicating a higher attraction to mechanization in crop harvesting. The total import of machines shows an average annual value of 38 million USD in the last few years, with a significant rise in 2021. The total annual import value exceeded 56 million USD in 2021 due to the high volume import of 2WT, threshers, reapers, and water pumps.

7) Mechanization by Application Stages

The most notable agricultural operations mechanized in Nepal are the tillage and threshing of grain crops. In the Terai region, over 70% of tillage operation and nearly 100% of rice and wheat threshing have been mechanized. The mechanization is still poor in crop seeding, planting, and weeding. For most crops, crop management practice is limited to pumping irrigation water and spraying pesticides. Farmers are reluctant to mechanize post-harvesting operations. Some cooperative groups have recently started using portable dryers for rice drying. Milling of most food crops stands mechanized at the entrepreneurs and industry levels.

Table 3.2.5. Mechanization Clustered by Application Stages, Major Crops

Major Crops	Cultivation Stages				
	Land preparation	**Seeding / Planting**	**Crop Management**	**Harvesting / Threshing**	**Post - Harvesting**
Paddy	Tractors, Power tillers, Plough, Disk harrow, Cultivator Rotavator	Drum seeder Transplanter (Limited scale)	Sprayers Water pumps Solar Pumps	Reapers, Thresher Winnowers Combine harvester	None
Wheat	Tractors, Power tillers, Plough, Disk harrow Cultivator	Seed drill (Limited scale)	Sprayers Water pumps Solar Pumps	Reapers, Thresher Winnowers	None
Maize	Tractors, Power tillers, Plough, Disk harrow Cultivator	Seed Planter Jab planter (Limited scale)	Sprayers Water pumps Power weeder	De-huskers Shellers Threshers	None
Lentils	Tractors, Power tillers, Plough, Disk harrow Cultivator	None	Sprayers Water pumps	None	None

Oil seeds	Tractors, Power tillers, Plough, Disk harrow Cultivator	None	Sprayers Water pumps	None	None
Sugarcane	Tractors, Plough, Disk harrow Cultivator Rotavator	None	Water pumps Sprayers	None	Jaggery Making (Limited Scale)
Potato	Tractors, Power tillers, Plough, Disk harrow, Cultivator Rotavator	Potato planter (Limited scale)	Sprayers Water pumps Solar Pumps	Potato harvester (Limited scale)	None
Vegetables	Tractors, Power tillers, Mini tiller, Plough, Disk harrow, Cultivator	None	Sprayers Water pumps Solar Pumps Micro irrigation	None	None
Fruits	Tractors, Power tillers, Plough, Cultivator	None	Sprayers Water pumps Micro	None	Solar drying (Limited

8) Gaps in Mechanization

The above table 3.2.5 summarizes the gaps in mechanization by application stages of different major crops. Across the crop sectors, the adoption of mechanization appears relatively high in rice, wheat, and maize production and least for fruits and vegetables. It is also evident that land preparation is a highly mechanized operation, and post-harvesting is the most neglected operation for all the crops.

Land Preparation: The mechanization of land preparation operation is well covered by the tractors, power tillers and their soil working implements. For most vegetables, field bunds and raised-beds are usually preferred for cultivation. Farmers are manually making the raised beds and bunds as the generally available implements are not useful. There appears to be a gap in mechanization to introduce raised-bed makers and bund former to benefit vegetable growers.

Seeding and Planting: Various types of seeding and planting machines have been introduced in the country; however, their adoption is limited to a small scale. Most farmers are still manually transplanting rice, and sowing wheat and maize traditionally. Farmers see a clear advantage of using rice transplanters but are hesitant in its adoption. For small grain crops like lentils and oil seeds, no specific seeding equipment is available. Similarly, sugarcane planting and vegetable transplanting are carried out manually due to the non-availability of appropriate technology machinery in the country.

Crop Management: Mechanization of crop management practices is largely confined to using sprayers and water pumps for most crops. In recent years, solar pumps have been used for improved irrigation management. Weed control and fertilizer application are two important activities for the proper growth and yield of crops. Farmers largely carry out these activities manually, which is time-consuming and expensive. This seems to be another mechanization gap area and needs the introduction of efficient weed control equipment and fertilizer broadcasters for better and effective crop management.

Harvesting: The increasing numbers of reapers, threshers, and combines in the Terai districts largely cover the mechanization of rice and wheat harvesting. However, appropriate harvesting technology for lentils, oil seeds, and sugarcane is still missing in large areas. Farmers often find the high cost of labor to be the limiting factor in benefiting from their cultivation.

Post-harvesting: This is the least priority segment for most crops at the farmers' level. If farmers could execute some primary post-harvest operations (cleaning, grading, drying) of cereal grain, pulses, oilseeds, fruits, and vegetables, that would bring better prices for their produce. Promotion of portable type grain dryers could bring a rational change in mechanization of post-harvest operations of cereal grains. Other potential post-harvest activities include the mechanized small-scale pulse milling, oil and juice extracting, grading and drying of fruits and vegetables at the community level.

9) End-User Profile

The details of average size holdings for different categories of farmers in Nepal are shown in Table 3.2.6. The majority of farmers (over 68%) fall in the marginal class with an average holding of 0.44 ha. Farmer's average holding size for all categories of farmers in Nepal is 0.68 ha, one of the lowest holding sizes in Asia. The average land holding size was 0.96 ha in 1992 and it shrank to 0.68 ha in 20 years due to the increase in the total number of holdings (Table 3.2.7).

Table 3.2.6. Average Size of Operational Holdings by Different Size Classes, (2011-12)

Major size class		Number of total holdings	Total holding area (ha)	Average size of holdings (ha)
Marginal	< 1.0 ha	2,615,482	1,159,943	0.44
Small	1.0 – 2.0 ha	548,974	749,810	1.36
Semi-medium	2.0 – 4.0 ha	168,871	442,921	2.62
Medium	4.0 – 10.0 ha	25,625	134,541	5.25
Large	10 ha & above	1,054	15,227	14.45
All size class		3,831,093	2,525,639	0.68

Source: CBS (2013)

Table 3.2.7. Changes in Average Size of Operational Holdings

Particulars	1992	2002	2012
Total number holdings ('000)	2,736	3,364	3,831
Area of holdings ('000 ha)	2,599	2,654	2,525
Average holding size (ha)	0.96	0.80	0.68

Source: CBS (2018)

The medium and large class farmers have higher earnings and have been investing in mechanization since long. They have rich experiences of using machines on their own farms and hiring out for others to make additional earnings. The smallholder farmers usually have limited earnings to invest in the mechanization assets. For their small landholdings, they often hesitate to buy and own the machines; instead, they would prefer to hire from others. However, most farmers cannot own heavy and expensive machines; they are using all types of modern machines for almost all production phases. Generally, the owner farmer, service provider or community-based custom hiring centers (CHCs) are providing the mechanization services on a hiring basis.

Prime Minister's Agriculture Modernization Project:

Prime Minister's Agriculture Modernization Project (PMAMP) is the largest existing agricultural project in Nepal under the Ministry of Agriculture and Livestock Development. The 10-year project spans from FY 2016 to 2026, and the estimated budget is 1.2 billion USD. The project consists of four components including Pocket, Block, Zone, and Super Zone for specific commodity production. Modernization and commercialization of agriculture through mechanization and linking agriculture to industries are the two major objectives of the project. The project provides technical support and financial subsidies on purchasing machines and equipment (mostly 50%) to the farmers and entrepreneurs of the project area.[21]

The establishment of Custom Hiring Centers (CHCs) and Post-harvest centers (PHCs) are the two important activities of the PMAMP project. The project has set good examples of establishing different scale CHCs nationwide. It has established 569 small to medium CHCs so far, and many more are in the process of completion.[22] The project is providing up to 50% subsidy capital on the purchase of machines for each CHC. As per the geography and crop specific requirements, almost all types of farm machines are promoted by the project through the CHCs. Tractors, threshers, shellers, reapers, water pumps are the most widely marketed machines. In addition, land levelers, rice transplanters, combines, and dryers are also promoted through the project for specific groups of farmers. So far, the project has distributed over 12,000 small- and large-scale machines and equipment to the user farmers through the subsidy programme.[22] This has not only added to the number of machines in the countryside but also increased machinery access to all farmers.

10) Current unmet Needs

So far, agricultural mechanization has been concentrated in paddy, wheat, and maize crops. By operation, mechanization has mainly concentrated on land tillage, crop harvesting, threshing, and irrigation. Operations like seeding/planting, interculture, and post-harvesting are still lagging behind in mechanization. Although the rice transplanter was introduced earlier in the country, the manual labor still carries a large share of rice transplanting. The adoption of rice transplanters is slow due to its specific technical requirements and high initial cost. It is still an unmet mechanization need.

Mechanization of seeding, planting, and harvesting operations of small grain crops like oilseeds and lentils is very limited due to their specific requirements. The introduction and upscaling of efficient seeding and harvesting machines for these small grain crops appears as another unmet need. Sugarcane is established as an industrial crop in Nepal. Except for the land preparation and transportation, all other operations of sugarcane production are not yet mechanized. Sugarcane planters and harvesters need to be introduced in the Terai region. Due to the high initial cost, sugarcane planting and harvesting mechanization has not started yet. Minimum tillage and other conservation farming technologies were introduced earlier in Nepal. However, farmers are still reluctant to adopt this technology. Cleaning, grading, and drying technologies for crop grains, fruit, and vegetables are also unmet post-harvest mechanization needs of the Nepalese farmers.

11) Demand

The main factors that cause Nepalese farmers to use agricultural machines include shortages of farm labor, increased rural wage rates, government subsidies supporting the purchase of machines, and availability of a variety of machines in the country. In the past, there was no support through government subsidies, and the agricultural machinery was bought only by the large holder farmers. The most highly demanded agricultural machines were the four-wheel tractors, threshers, and diesel engine pumps. After the introduction of the Agriculture Mechanization Promotion Policy in 2014, the government has started providing capital subsidies for agricultural machinery to the farmers. This enabled the smallholder farmers to buy machines of their own choice, leading to higher demands for small-scale machines in recent years. Farmers are much attracted by power tillers, mini tillers, reapers, and threshers since these machines are highly remunerative and could pay off the capital cost quickly.

As per the evidence of previous studies, even in smallholder farming systems of Nepal, farm size influences farmers' willingness to purchase any assets of mechanization. The presence of animal power, income per capita, per capita farm area, household size, and farm area are significant determinants for total investment in farm mechanization. Above all, increasing farm income is crucial to increasing the total investment in farm mechanization.[23] Machines with multiple functions, which could be used for non-farm activities, are the major determinant of demand. Hence, there is high demand for tractors, power tillers, and threshers due to their multiple-use character which entails the possibility of making

additional earnings. The demand for heavy machines like combines and land levelers is also increasing, led by innovative farmers who aim to provide rental services and generate extra income.

Quite often, the household's disposable income through remittance creates demands for machines in rural areas. Changes in bank interest rates, fluctuations of fuel and electricity prices also have some cyclic effects on machinery demand. Currently, the government is encouraging farmers and other private sectors to use electricity instead of petroleum fuel and providing different discounts on the electricity price. The electric power in Nepal is mostly generated from hydropower, which is clean and relatively cheap. The government reviewed the electricity tariff rate in October 2021 and has set the lowest tariff rate as 0.018 USD per kWh for irrigation water pumping, and for most other purposes it is more than 0.063 USD per kWh.[24] The government has planned to further reduce the electricity rate for irrigation to 0.01 USD per kWh in the near future. Similarly, the government is also providing 50% subsidy on electricity bills to the cold storages and dairy industries. With this policy, it can be expected that the demands for irrigation water pumps and other motorized machines will increase in the future.

Consistency of Demand

During the last couple of years, the market demand for agricultural machines in Nepal has been highly guided by government subsidy programme, and plenty of machines have been acquired through it. However, many tractors, plowing implements, and threshers are also bought outside this programme. The subsidy support greatly influences the overall annual demand for mechanization. For example, 95% of the mini tillers in the market are in the mid hills, which were purchased mainly within the government subsidy programmes. As per consultation with the distributors, they confirmed that it would be difficult to make sales if the subsidies were removed.[18] However, there is concern on the market distortions among the traders and other stakeholders vis-à-vis the continuity of the government's subsidy programmes.

The demand for machinery generally shows a temporal fluctuation with the government annual expenditure process. Since the Nepal fiscal year starts in mid-July and ends in mid-June, most of the procurements, including for farm machines, are carried out in April, May, and June. Almost 60% of machines are sold in these three months. The sales of harvesting and threshing machines peak before the harvest season of paddy in October and November. The harvest schedule is a major consideration for importers to schedule the delivery of imported machines.[18]

In general, the consistency of market demand depends on the type and purpose of the machines; for instance, tractors, tillage implements, and trolleys are always in demand due to their multipurpose uses.

12) Supply Chain

The supply chain of agricultural machinery from manufacturers to end-user farmers in Nepal is

represented in a flow diagram, as shown in Figure 3.2.4. Nepal has been primarily an importer of agricultural machines and equipment for decades. Majority of the machines are imported from the manufacturers of China and India, and few specific machines are also imported from Germany, Türkiye, Japan, and Republic of Korea. Machines' domestic production is limited to simple tools and implements like de-husker, shellers, threshers, cage wheels, trolleys, and some hand tools.

There are around 40 small and big importers of agricultural machinery in Nepal, who import the majority of machines directly from manufacturers and, in some instances, through established trading companies. After import, the importers distribute the machines in three ways: one is through their own distribution centers, the second is through independent dealers, and the third is through rental service providers. The machines are sold directly to the farmer-users or through the cooperatives, farmers groups, and rental service providers from the distribution centers and dealers. Local manufacturers usually sell their products directly to the user farmers and also through independent dealers. Thus, the end user farmers are obtaining the machinery service either by purchasing the machines themselves or on a rental basis from the cooperatives, farmer groups, and local rental service providers.

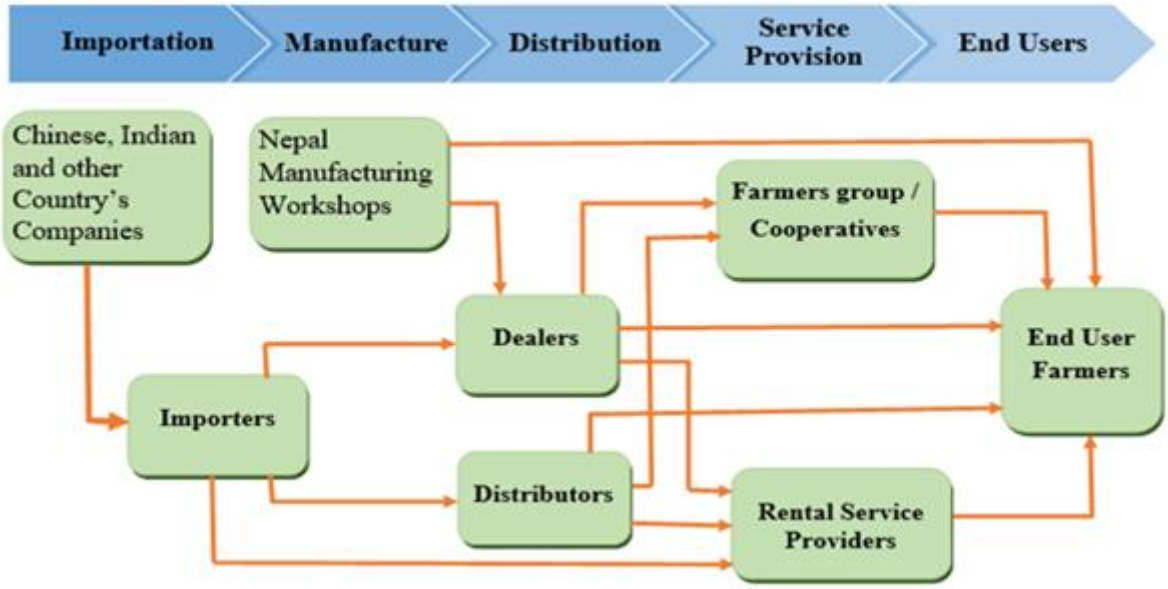


Figure 3.2.4. Supply chain of agricultural machinery and equipment in Nepal

Key Stakeholders in the Supply Chain

The importers, manufacturers, dealers, distributors, and rental service providers are the five key stakeholders of the agricultural machinery supply chain of Nepal. The majority of importers also have their own distribution centers as sales points; therefore, it is convenient to understand importers and distributors as a single actor of the supply chain.

Importers: Among the various actors of mechanization, importers and distributors play a vital role in choosing and bringing in the suitable type, size, and quality of machines for the end users. Usually, the importers set up their

distribution centers across various towns to display their machines. These machinery distribution centers act as the point of sale of machines and provide after-sales services and spare parts. Through their business network, they supply a variety of small and large machines in the country to meet all possible needs of farmers.

Manufacturers: Since most of the imported farm machines come from the manufacturing companies of China and India, their manufacturing strategy largely affects the types, size, and volume of products available in the market. In general, Indian companies manufacture large-sized machines suitable for plain areas. Products from India dominates in the Terai region of Nepal since it has similar socio-economic conditions to adjoining Indian states. The Chinese products are gaining popularity in hilly regions, as they are designed specifically for smaller plots of hill slopes. The small-scale local manufacturers usually fabricate simple equipment like iron ploughs, threshers, and trolleys that are directly sold to local buyers.

Dealers: Dealers are the authorized sellers of machines of specific companies. For Indian tractors and other machines, the dealer network in Nepal is well-developed throughout the country. But for the Chinese products, the dealer network is not so well developed, and the importers sell through distribution centers. There are some independent dealers and agents who sell machines from various importers. Usually, they are in a better position to supply more than one brand of machine. They also provide after-sales services and spare parts to their customers.

Rental Service Providers: The rental service providers in Nepal are either large farmers or farmer group cooperatives that purchase the equipment and rent it out to small-scale farmers who cannot afford to purchase their machines. Farmers who own agricultural machines with larger holdings rent them out when they do not need them on their farms. Indeed, the rental service providers are playing a pivotal role in enhancing agricultural mechanization in the country; however, they are the least represented actor in the value chain.

13) Access to End-Users

The Nepal Agricultural Machinery Entrepreneurs Association (NAMEA) is an industry association formed in 2015. It jointly organizes national exhibitions of mechanization in different parts of the country every two years. The exhibitions effectively demonstrate all types of the latest agricultural machines and equipment from several national and international importers, traders, and manufacturers. Thousands of visitors, mostly farmers, cooperative groups, service providers, government officials, students, teachers, and policymakers visit the exhibitions and acquire information about scores of types of machines and technologies in a single place.

They actively participate at agricultural fairs and exhibitions with specific samples of new products and distribute brochures and booklets to the farmer groups and other concerned groups. They also conduct specific field demonstrations and training sessions about their machines and technologies jointly with their local dealers and distribution centers. Young farmers are also

gathering information about different makes and models of machines and technologies through the internet by visiting the websites of respective manufacturing companies.

14) Accessibility to Products

The private sector is playing a significant role in introducing the varieties of agricultural machines to Nepal from different countries and making them available through their district distribution outlets. The government started providing capital subsidies on the purchase of farm machines (up to 50%) to individual farmers and farmers' cooperatives through different programmes. The private sector also expanded their business networks to meet the rising demands. This has improved the availability of machines at local levels and minimized the cost due to intensified competition among the private sector. In the last couple of years, the numbers of private rental service providers and community CHCs have increased significantly in the rural areas, which has also substantially improved the farmers' accessibility to various types of machines and equipment.

Other governmental development projects like rural road construction and rural electrification are also helping increase the accessibility of machines and their easy penetration in rural villages. Though there is not a straightforward link between outmigration and mechanization, the evidence reviewed interestingly suggests that the increased use of small and inexpensive implements in agriculture has not just been due to labor shortages but also to the greater resources available through the remittances.

15) Services Support

With the growing trend of the machinery business, most distributors and dealers have developed workshop facilities with mechanics to provide after-sales services to the end users. They have developed improved facilities for spare parts and repair services for machines like tractors, power tillers, threshers, and water pumps. The sellers provide a warranty of one year's free service for these machines, usually of Indian origin. However, for the other machines like mini tillers, transplanters, harvesters, and levelers, spare parts' and after-sale service availability are not so well established yet. Farmers often complain about their service support facilities.

16) Financial Support Availability

The availability of financial services to the agriculture sector in Nepal is questionable. The government has encouraged the banks to provide loans to farmers for their agricultural business by mandating that 10% of their loan portfolios be allocated to the agricultural sector. Despite this mandate, banks are reluctant to channel their resources to the farmers and consider smallholder farmers as high-risk clients for their business. There are no special credit facilities for farmers to invest in mechanization. Very few farmers have access to bank loans with their land property as collateral. Most of these resources are available for poultry and animal husbandry production rather than farm mechanization.

Table 3.2.8. Annual Credit and Average Interest rates of Banks for Agricultural Sector

Credit Types	Annual Loan Amount and Average Interest (%) (NRs in 100000)			
	2018	2019	2020	2021
Agriculture and Forestry Related	95,936.04 (12.46 %)	130,561.65 (11.47 %)	163,056.24 (10.37 %)	229,954.00 (7.98 %)
Fishery Related	2,307.10 (12.16 %)	3,426.72 (11.03 %)	4,751.44 (9.95 %)	7,179.51 (7.55 %)

Source: NRB (2021)

The banks are releasing very few percentages of their loans to the agricultural sector, and the interest rates usually remain over 11%. Many farmers in Nepal are associated with groups & cooperatives, which conduct saving and credit activities for their members, connecting with the formal banking systems. Farmers connect with these types of groups/cooperatives and have some level of credit facilities. A certain percentage of such credits is being used to purchase small-scale farm machines in rural areas. The interest rates for such credits are usually higher than 15%.

17) Sustainability Issues

With the continuous efforts of the private sector and governmental support policy, agricultural machinery can be accessed at every level of production in Nepal. Though the market provides all categories of machines, the mechanization process is constrained mainly by the domination of small and marginal farmers, increasing fragmentation of land holdings, and limited farming income. However, farmers' machine ownership has risen significantly in recent years with the governmental subsidy programme. But there arises a question of sustainability: what if there will be no such subsidy support in the future? Therefore, there is a need to train the farmers and entrepreneurs to develop a systematic business plan to fully utilize the machines that can generate optimum returns on their investment so that in the future they can purchase other kinds of machines with their savings.

Recently, with the increasing outmigration of youth, women and the elderly have played a bigger role in the agricultural sector. The youth and women groups are attracted to modern agricultural machines and are participating in using them on their farms. However, there is a lack of access roads to farms, particularly in hill slopes, which creates additional challenges to the female operators to transport machines to their farms. Thus, there is demand for more women-friendly machines that are smaller, more convenient, and easier to operate. Empowerment of women through field demonstrations and operators' training, including maintenance and repair services, is also important for the sustainability of rural mechanization.

Farming machines like minimum tillage implements and zero-till seed drills, working on the principle of resource conservation technology (RCT), are also available in the market. The

research institutions have also tested and recommended to upscale the technology. Despite the availability and potentiality of the technology in resource conservation, farmers are reluctant to use the technology on a larger scale. Technological knowledge gaps of RCTs, weed management problems, and the strong mindset of traditional farming practices of farmers are the major constraints of RCTs for gaining popularity among the farming communities. It requires additional efforts from all stakeholders to streamline RCTs in the agricultural mechanization process and to cope with the emerging climate change challenge.

18) Conclusions

The adoption of farm mechanization has been growing through time in Nepal, mainly due to the government's soft tariff policy on the imports of agricultural machinery, capital subsidy on the purchase of machines, and establishment of community-based CHCs. Despite the low ownership of farm machinery, farmers are using all types of machines in their farming operations due to the emerging CHCs and hiring out services throughout the country.

Nepal is a net importer of agricultural machinery with no exportable items. In 2021, the country imported over 56 million USD in machines, primarily from India and China. In Nepal, the agricultural project PMAMP and the private sector have played a key role in disseminating all categories of farm machines in the country in the last few years.

Tractors (2WT & 4WT) and the tillage implements are Nepal's most popular farm machines. Land preparation by tractors and crop threshing with threshers are the two leading segments of mechanization. Reapers and combine harvesters have also gained popularity in recent years. However, the crop stand establishment machines have a high scope for mechanized farming of most crops as their current usage is very limited. Although the rice transplanter was introduced earlier in the country, its adoption rate is very low due to high initial cost and specific technical requirements. Therefore, this is still an unmet mechanization need of Nepalese farmers and calls for the introduction of more efficient and cost-effective mechanization technologies.

The major constraints in agricultural mechanization development in Nepal include small landholdings and increased fragmentation of the land holdings. The continuous division of land holdings may lead to the underutilization of machines and will not justify machinery costs in the future. The concept of CHCs appears as an essential mechanism to improve the affordability of machines by small farmers and fully utilize the machines. The public-private-partnership model of CHCs will be more appropriate for sustainable mechanization in the future. By developing some systematic business plan to efficiently run the CHCs, their role can be increased significantly for sustainable agricultural mechanization in the country.

19) Recommendations

- The current business management systems of importers and distributors are inefficient and need improvement. Modern business tools and

systematic market approaches such as customer satisfaction surveys, price sensitivity analysis, and review of after-sale services should be made an integral part of their businesses. The importers and traders should arrange regular technical training about their machines for rural youth to develop a pool of technically skilled manpower at the grassroot level. These trained youth could not only repair the field machines but also work as local agents to promote mechanization.

- After-sale services and availability of spare parts of machinery are key factors considered by farmers in making their purchasing decisions. Often, there are issues with after-sale service and spare parts availability, especially for modern machinery like rice transplanters, land levelers, and combine harvesters. The manufacturers and suppliers should effectively manage this shortfall to support the farmers and their businesses.

- A robust national R&D team should work continuously on the development and testing of locally manufactured and imported machines to ensure the efficiency and performance of the imported machinery and implements. The machinery importers and traders should work in collaboration with the R&D team for the attainment of sustainable agricultural mechanization. Stakeholders in the supply chain must focus on manufacturing and introducing scale-appropriate and more women-friendly machines that are smaller and more convenient to operate.
- The government should bring policy instruments to encourage farmers in land consolidation and mechanized farming. The machinery renters and the farmers should also be encouraged to adopt conservation agriculture practices through different incentives and outreach visit programs of successful resource conservation farming areas. Development and upscaling of appropriate CA machinery shall be further prioritized.

- As the present demand for agricultural implements is mostly catered through imports and its demand is expected to grow further in the future, there is a high need to establish specific manufacturing companies to reduce high import dependency. The machines and spare parts are all imported and may not lead to the national capacity building process and sustainable agricultural mechanization in the country. In this regard, governments should formulate targeted policies to motivate the private sector to invest in domestic production. In this connection, provision of soft loans, review of custom duty and import tax policy on raw materials and discounts on electricity tariffs are essential to encourage the private sector to invest in local agricultural machinery manufacturing.

C. Russian Federation Country

Market

1) Agricultural Profile, brief overview

The Russian Federation is a transcontinental country spanning Eastern Europe and Northern Asia. With an area of 17,098,242 km², the country is the largest country in the world by area and covers more than 11% of the Earth's landmass. However, vast regions of the country are uninhabited or uninhabitable. The Russian Federation shares borders with 14 countries. Most of the country has a continental climate, with long, cold winters and brief summers.

The nominal volume of GDP of the Russian Federation in 2021 amounted to 130,795.3 billion rubles. In 2021, the share of the agriculture sector declined by 1.3% after rising by 0.2% in 2020. On the whole, the economic contribution of agriculture declined for the first time since 2012. During the period of growth in 2013-2020, the output of the Russian agricultural sector increased by almost 20%, and its share of Russian GDP reached 4.5% according to Federal State Statistics Service (ROSSTAT). The decline in economic output in agriculture is associated with the negative dynamics of the harvest in 2021 the gross grain harvest decreased by 9.1%, according to ROSSTAT.

The Russian Federation has a unique agricultural potential - being one of the largest grain-growing and grain-processing regions of the world, it has 9% of the world's arable land, 55% of chernozem soils, and 8.3% of the planet's renewable water resources. The future of Russian agriculture lies in the use of high-performance and highly profitable technologies, which in turn are the basis for achieving the competitiveness of Russian food products.

Table 3.3.1. Crop areas and structure of crop areas in farms of all categories of the Russian Federation, thousand hectares

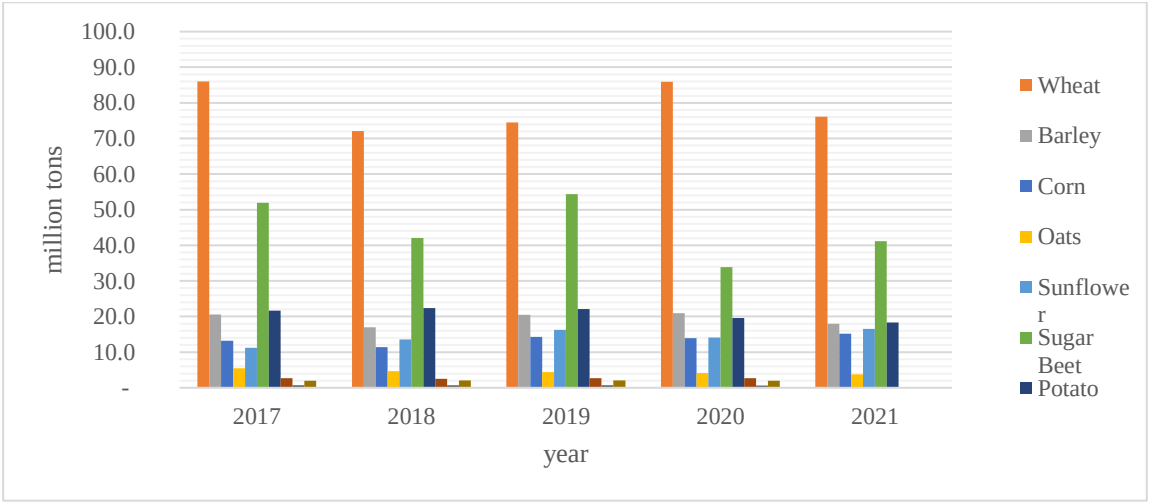
Type of Area	2010	2016	2017	2018	2019	2020	2021
Total Agricultural area	74,861	79,312	80,049	79,634	79,888	79,948	80,437
Cereal and leguminous crops - total	43,203	47,100	47,705	46,339	46,660	47,900	47,006

Source: Federal State Statistics Service (ROSSTAT)

The total agricultural area in the Russian Federation in 2021 was 80,437 thousand hectares. Most of the sown area is used for grain and leguminous crops (58% in 2021), including wheat - 36%, barley - 10%, corn - 4% and oats - 3%. The rest are fodder crops (21%), industrial crops (16%), potatoes, and vegetable crops (4%). In ten years (from 2010 to 2021), the cultivated land area has grown by 7% (Source: Strategy for developing the agro-industrial and fishery complexes of the Russian Federation for the period up to 2030). Agricultural lands occupy 13% of the territory of Russia. Russia's most important crops are wheat, sugar beet, potatoes, and cereals (corn, barley, and oats).

Thanks to the state policy for the development of agriculture, the Russian Federation is currently the world's largest producer of barley, ranks 2nd in the production of sunflower seeds, 3rd in the production of potatoes and milk, 4th in the production of wheat, having become in recent years the largest exporter of this crop, and 5th in the production of eggs and chicken meat (Source: Strategy for the development of the agro-industrial and fishery complexes of the Russian Federation for the period up to 2030).

Figure 3.3.1. Gross yield of main crops in Russian Federation, 2017-2021, million tons



Source: ROSSTAT

The dynamic of gross yield of main crops in the last five years is demonstrated in Figure 3.3.1. The first fall was in 2018. Unfavorable weather conditions in several Russian regions negatively affected the gross harvest of agricultural crops. According to the Ministry of Agriculture of the Russian Federation, in 2018, as a result of the loss of crops from drought, an emergency status was declared on the territory of five regions, and an emergency status was also declared in eight other areas of the Russian Federation as a result of waterlogging of the soil. According to the agency, the loss of grain harvest in the Russian Federation in 2021 due to weather conditions amounted to about 30 million tons. The Russian Federation in 2021 collected 121.4 million tons of grain against 133.5 million tons a year earlier. Thus, there was a decline of 10%, according to ROSSTAT data published in early March 2022.

According to the statistics of the ROSSTAT, the wheat harvest in the Russian Federation by the end of 2021 amounted to 76 million tons, including 53 million tons of winter wheat (in 2020 – 63.2 million tons) and 23 million tons of spring wheat (2.7 million tons in 2020). The rye harvest amounted to 1.7 million tons against 2.7 million tons a year earlier, corn – 15.2 million tons against 13.9 million tons, barley – 17.99 million tons against 20.9 million tons. According to ROSSTAT, in 2022, the Russian Federation increased agricultural production by 10.2%. In crop farming - by 15.9%, in livestock farming - by 2.4%.

According to the materials of the department published on 29 December 2021, the main share of grain (68.5%), sugar beet (90.7%), and sunflower (63.7%) is grown in agricultural

organizations; potatoes (64%) and vegetables (52.1%) are produced in households. In farms, 30.3% of the total grain harvest was collected, sunflower seeds - 35.9%, sugar beet - 9.2%, and vegetables - 20.7%.

Table 3.3.2. Average prices of producers of agricultural products sold by agricultural organizations, 2017 – 2021, Q1 2022, US dollars per ton

	2017	**2018**	**2019**	**2020**	**2021**	**Q1 2022**
Grains and legumes	127.70	135.79	159.39	164.94	194.00	181.94
Wheat	125.18	136.14	158.77	169.64	193.68	179.36
Barley	116.22	129.40	147.54	135.03	174.39	172.28
Corn	120.49	126.14	155.38	150.81	187.20	168.18
Oats	111.74	95.20	106.22	117.94	145.91	141.51
Sunflower	291.90	283.50	279.38	340.13	525.83	433.64
Sugar Beet	158.52	168.72	163.36	141.45	212.06	249.36
Potato	198.91	200.12	163.03	163.71	238.01	260.17
Cabbage	165.02	188.58	246.09	191.97	244.05	442.50
Cucumbers	1,302.25	1,139.88	1,194.50	1,013.46	1,140.39	1,478.65
Tomatoes	1,216.26	1,135.83	1,312.12	1,203.96	1,353.20	1,779.56

Source: Unified interdepartmental information and statistical system (FEDSTAT)

According to FEDSTAT, the average prices for nearly all major agricultural crops in the Russian Federation over the past five years increased (Table 3.3.2). The price of grains and legumes was increased by 52% from 2017 to 2021. Notably, the average price of wheat was increased by 55%, the average price of barley was increased by 50%, the price of corn was increased up to 55%, of oats – by 30%, of sunflowers – up to 80%. The price for sugar beat was increased by 34%, and of potato by 30%, while cabbage was increased by 48%, and tomatoes 11%. The price of cucumber was lowered by 13%.

2) Agricultural Mechanization

Over the past 15-20 years, the Russian agricultural machinery market has become part of the global market, particularly for producing machinery. Its potential is estimated at 5-7 billion US dollars per year.

The number of industry employees at the end of 2021 was 41.8 thousand people, according to the statistical portal of the Russian Association of Specialized Machinery and Equipment Manufacturers (ROSSPETSMASH STAT), which corresponds to a growth of 5.5% from 2020 (ROSSTAT).

The local agricultural machinery industry in the Russian Federation is producing a wide range of agricultural machinery. More than 150 local agricultural machinery manufacturers are

producing various equipment, but the main products are crushers for feed, cultivators, mini tractors, plows, rippers, poultry equipment, harrows, and agricultural loaders.

The prominent agricultural machinery manufacturing companies are members of the Russian Association of Specialized Machinery and Equipment Manufacturers (ROSSPETSMASH) and Concern Tractor Plants (production of agricultural tractors, reclamation machinery and equipment, combine harvesters, and trailed and mounted agricultural machinery). They account for 80% of all machinery produced in the country.

Table 3.3.3. Agricultural Machinery Market, 2017 – 2021, billion US dollars

Item	2017	2018	2019	2020	2021
Total domestic production	2.4	2.1	2.1	2.3	3.4
Production that meets National localization requirements	1.8	1.7	1.8	2.1	3.0
Total assembly	0.5	0.4	0.3	0.3	0.4
Import	1.3	1.6	1.3	1.5	2.6
Export	0.1	0.2	0.2	0.2	0.3
Market	3.6	3.5	3.1	3.6	5.3

Source: ROSSPETSMASH STAT

According to ROSSPETSMASH STAT, in the last five years (2017–2021), the total market of agricultural machinery has grown by 47% from 3.6 billion US dollars in 2017 to 5.3 billion US dollars in 2021. The total domestic production of agricultural equipment, including assembly in the Russian Federation, increased by 42% from 2.4 billion US dollars in 2017 to 3.4 billion US dollars in 2021. Production that meets national localization requirements (excluding assembly of foreign equipment) amounted to 3 billion US dollars in 2021, 66% higher than in 2017.

The import of agricultural machinery by the end of 2021 amounted to 2.6 billion US dollars, it was 49% of the total Russian market of agricultural machinery. Over the past five years, the imports have doubled. The main import origins in 2021 were Belarus – 23% of total imports, Germany – 22%, USA – 20%, Brazil – 7% and 5% from Mexico; while 23% imports were from other countries.

Export of Russian agricultural machinery amounted to around 300 million dollars in 2021, three times higher than the amount in 2017. The Russian Federation exports all kinds of agricultural equipment. Main destinations in 2021 were Kazakhstan – 73% of total exports, Belarus – 6%, Ukraine – 3%, Moldova – 3%, Germany – 2% and 13% to other countries.

Table 3.3.4. shows the statistics of the fleet of the main types of equipment in agricultural organizations in the Russian Federation, according to the ROSSTAT data. Statistics are presented for agricultural enterprises without considering the private households, peasant farms, and farms of individual entrepreneurs.

Table 3.3.4. Fleet of the main types of equipment in agricultural organizations in Russia, 2017-2021,

thousand units

Type of machines	2017	2018	2019	2020	2021
Tractors	216.8	211.9	206.7	203.6	198.3
Plows	59.7	58.5	56.9	56.7	55.2
Cultivators	87.6	84.8	82.6	81.2	78.4
Sowers	82.8	79.0	74.8	70.9	66.7
Combines:					
Grain harvesters	57.6	56.9	55.0	53.9	52.6
Maize harvesters	0.7	0.6	0.6	0.6	0.6
Flax harvesters	0.3	0.3	0.2	0.2	0.2
Potato harvesters	2.1	2.0	2.0	1.9	1.8
Forage harvesters	12.7	12.3	11.8	11.4	10.9
Beet harvesters (without haulm harvesters)	2.2	2.1	2.1	1.9	1.9
Mowers	30.5	30.1	29.8	29.3	28.7
Balers	19.9	19.6	19.5	18.7	18.2
Headers	19.1	18.8	19.1	19.1	19.3
Sprinkling machines and irrigation machines and equipment	6.2	6.1	6.4	6.7	7.1
Fertilizer spreader	15.5	15.7	15.7	16.1	16.2
Fertilizer applicator for:					
Hard organic fertilizer	4.7	4.5	4.5	4.6	4.6
Liquid organic fertilizer	3.7	3.8	4.1	4.1	4.1
Tractor sprayers and dusters	23.1	23.5	24.3	24.8	25.1
Milking parlor and aggregates	22.9	22.4	21.9	21.3	20.0

Source: ROSSTAT

Agricultural machinery production in the Russian Federation is concentrated in 6 key segments in which domestic companies have retained significant competencies:

- Tillage machines;
- Seeding technology;
- Equipment for chemical plant protection and application of fertilizers to the soil;
- Harvesting machines;
- Equipment for post-harvest processing of the crop; and,
- Tractors.

Table 3.3.5. Market of agricultural machinery by type, 2017-2021, million US dollars

Item	2017	2018	2019	2020	2021
Tillage machines					
Domestic production	139.3	119.1	123.1	151.6	251.3
Export	7.3	8.4	9.3	14.9	26.4
Import	0.9	7.1	7.3	9.7	13.9
Seeding machines					
Domestic production	128.2	118.6	126.6	161.3	242.2
Export	5.5	6.8	9.5	8.4	17.9
Import	44.5	15.8	13.9	22.4	31.9
Chemical protection and fertilization machines					
Domestic production	69.3	61.9	63.2	71.3	105.1
Export	0.8	0.7	3.1	2.8	6.8
Import	86.3	21.8	30.1	56.9	103.7
Harvesting Machines					
Domestic production	983.9	750.1	723.1	850.1	1,093.1
Export	77.3	99.4	94.5	108.4	113.8
Import	117.3	168.7	141.8	201.8	385.2
Post-harvesting Equipment					
Domestic production	61.6	64.1	71.6	95.9	129.7
Export	4.9	5.2	3.2	5.2	6.9
Import	0	0	0	0	0
Tractors					
Domestic production	553.0	606.1	528.1	588.5	852.0
Export	27.7	37.6	50.7	52.0	80.0
Import	87.0	487.1	510.0	487.7	710.6

Source: ROSSPETSMASH STAT

The main type of agricultural machinery produced in the Russian Federation is harvesting machinery, including grain and forage harvesters and various adapters for harvesting machines. Its share in total production in 2021 was 41%. In 2017, its share was 51%. The second main product is tractors, accounting to 32% in 2021, which was higher than its share in 2017 (28%). The shares of tillage and seeding machines were 9%. Post-harvesting equipment amounted to 5% of total production. The share of chemical protection and fertilization machines was 4%.

Harvesting machines accounted to 45% of agricultural equipment exports in 2021. The leading export destination in 2021 was Kazakhstan – 69% of total exports, Moldova 5%, and 4% were exported to Poland. The share of tractors in total agricultural machinery export was 32%. Tractors were exported mostly to Kazakhstan – 85% of total tractor's export, to Belarus – 8% and to Moldova – 2%. Export of tillage machines accounted for 10% in 2021. Around 92% of Russian tillage machines were exported to Kazakhstan, 2% were exported to Moldova, and 1% to Germany. Seven percent of total agricultural equipment export were represented by seeding machines. The main export region for seeding machines in 2021 was Kazakhstan – 87% of total exports; 9% to Ukraine; and 4% were exported to Belarus, Germany, and Estonia. The main destinations for Russian export of chemical protection and fertilization machines in 2021 were Kazakhstan – 60% of total exports,

Belarus – 18% and Moldova – 11%. More than 50% of exported post-harvesting equipment in 2021 were sent to Kazakhstan – 58%, Uzbekistan – 8% and Belarus – 7%.

Tractors accounted for over half of agricultural equipment imports (57%) in 2021. 41% of tractors were imported from Belarus, 25% were imported from USA, and 10% - from Germany. Harvesting machine imports amounted to 31%. More than 50% of harvesting machines in 2021 were imported from Germany (52%), 17% from Belgium, and 12% from USA. Eight percent of total agricultural equipment imports were represented by chemical protection and fertilization machines. The main import region for this type of machine was Brazil, where 74% of total chemical protection and fertilization machines were imported. Twelve percent were imported from the Netherlands and 6% from USA. Import of seeding machines in 2021 amounted to 3% of total agricultural machinery imports. In 2021, seeding machines were imported from USA (28%), France (26%), Ukraine (25%) and Mexico (21%). Only 1% of total imports were tillage machinery. 63% of tractors were imported from France, 28% from USA, 8% from Ukraine and 1% from Mexico.

Table 3.3.6. Production of agricultural equipment by type, 2017 – 2021, units

Type of Machines	**2017**	**2018**	**2019**	**2020**	**2021**
Tillage machines, total	**13,794**	**11,419**	**10,721**	**12,569**	**16,181**
Harrow	4,698	4,240	4,131	5,201	6,859
Cultivator	3,862	2,787	2,721	2,811	3,326
Plow	2,985	2,727	2,588	2,900	3,914
Deep tiller	182	147	180	316	421
Combined tillage aggregate	145	144	114	151	305
Other tillage machines	1,691	1,190	842	1,043	1,218
Seeding machines, total	**6,346**	**5,015**	**5,374**	**6,282**	**7,365**
Sower	6,186	4,931	5,122	6,147	7,165
Seed planter	147	79	250	126	195
Chemical protection and fertilization machines, total	**1,632**	**1,969**	**1,946**	**2,120**	**2,883**
Sprayers	1,058	1,172	1,329	1,355	1,899
Fertilizer applicators	557	778	611	700	848
Harvesting machines, total	**19,972**	**16,238**	**15,540**	**18,070**	**20,411**
Adapters for harvesting	11,993	10,470	10,267	11,603	13,060
Combines	7,504	5,490	4,975	6,115	6,936
Self-propelled mowers	475	278	298	352	415
Post-harvesting equipment, total	**4,455**	**4,595**	**4,196**	**5,304**	**6,407**
Grain cleaners	1,530	1,739	1,340	1,683	1,936
Grainers	248	309	310	472	613
Grain dryers	160	94	176	230	355
Other equipment	2,360	2,322	2,256	2,823	3,347
Tractors, total	**6,229**	**6,513**	**5,965**	**5,526**	**7,034**

Wheeled Tractors	3,393	3,501	2,954	1,604	1,882
4WD Tractors	2,362	2,533	2,452	3,087	4,170
Mini-Tractors	392	401	500	701	770
Crawler Tractors	82	78	59	134	212

Source: ROSSPETSMASH STAT

Harrows accounted for 42% of the total production of tillage machines in the Russian Federation in 2021. Plow production accounted for 24% and cultivator production – 20%. Russian domestic production in 2021 accounted for 94% of the total tillage machinery market. The export share of tillage machines in total agricultural machinery export of the Russian Federation was 10% in 2021.

Production of sowers accounted for 97% of the total production of seeding equipment in the country. Russian domestic production in 2021 accounted for 88% of the total seeding machinery market in the country. The export share of seeding equipment in total agriculture machinery export of the Russian Federation was 7%.

Production of sprayers accounted for 66% of the total production of chemical plant protection and fertilization equipment in the Russian Federation. Russian domestic production in 2021 was accounted for 50% of the total chemical plant protection and fertilization machinery national market. The export share of chemical plant protection and fertilization equipment was 3%.

In the combine group, there are combine harvesters (90% of total combined production in the Russian Federation), forage harvesters (9% of total production), and other harvesters less than 1%. This is the most competitive sector of Russian agricultural engineering in the global market, confirmed by the value of exports (45% of total agriculture machinery exports of the Russian Federation): 10% of domestic shipments. Russian domestic production in 2021 was accounted for 74%.

Production of grain cleaners accounted for 30% of the total production of post-harvesting equipment, grainers – 9% and grain dryers – 5%. Russian domestic production in 2021 accounted for 100% of total national post-harvesting equipment. And the export share of post-harvesting equipment was 3%.

Production of 4WD tractors accounted for 59% of the total production of tractors in the country. Production of wheeled tractors was 17% of total tractor production, mini-tractors – 11%, and crawler – 2%. Domestic production in 2021 accounted for 54% of total national tractor market. The export share of tractors in total agriculture machinery export of the Russian Federation was 32%. The Russian tractor market is dominated by tractors with a power range from 40 to 100 HP. Its market share was 45% in 2021. The market share of tractors under 40 HP was 29%, and more than 100 HP – 26%.

The general indicator of the level of agricultural mechanization development is the energy supply of sown areas (total installed power of engines of

tractors, combines, and other equipment, in kW/ha or HP/ha). According to the National Report on the Implementation of the State Program for the Development of Agriculture and Regulation of Agricultural Products, Raw Materials, and Food Markets in the Russian Federation, the energy supply of sown areas in 2020 was 1.51 HP/ha, and in 2019 it was 1,5 HP/ha. The renewal rate of tractors was 3.1% (in 2019 2.5%), combine harvesters - 4.8% (in 2019 3.8%), and forage harvesters - 4.5% (in 2019 3.9%).

A high level of mechanization in the Russian Federation has been achieved in basic fieldwork (tillage, sowing of cereals, planting of potatoes and sugar beets, harvesting of grain and fodder crops, potatoes, beets, harvesting of silage crops, haymaking, etc.). A low level of mechanization is observed in vegetable growing (like tomatoes, cucumbers, and cabbage). According to the estimation of the expert of the ROSSPETSMASH Association in the Russian Federation, there is 100% mechanization except for vegetable growing.

3) End-User Profile

Official statistics distinguish three categories of farms in the agrarian sector of the Russian economy:

- Agricultural enterprises (Commercial);
- Private households (Individual); and,
- Peasant farms and Individual entrepreneur farms (Groups / Cooperatives).

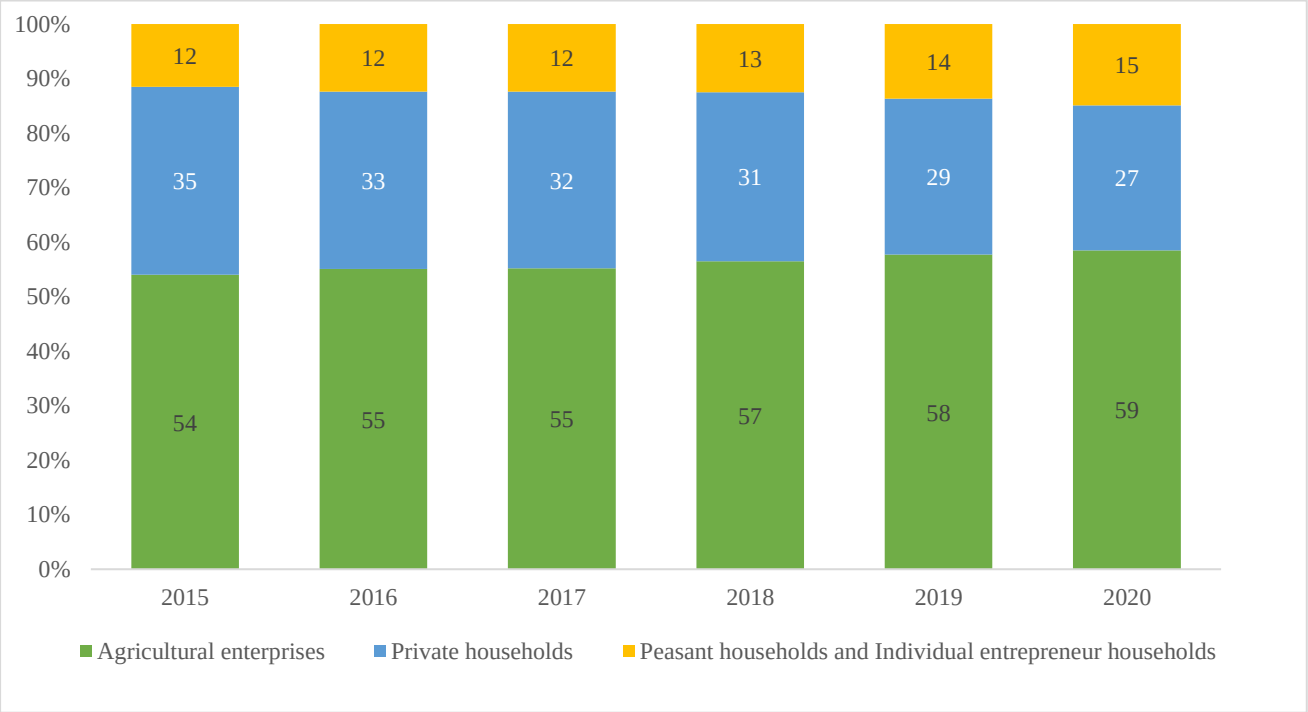
Table 3.3.7. Category of farmers, 2016 and 2021

Category of farmers	Quantity, thousand units		Crop acreage, thousand ha	
	2016	2021	2016	2021
Agricultural enterprises	36.0	32.9	54,615.9	52,435.8
Peasant and Individual entrepreneur farms	174.8	123.2	22,002.3	25,363.1
Private households	23,572.8	16,626.7	2,603.7	2,347.0

Source: All Russia Agricultural Census 2016, 2021

The All Russia Agricultural Census, which was held in 2016 and 2021, organized collection and registration of information and facts about the state of agriculture to obtain information about the factors and results of the agro-industrial sector of the economy. According to the results of the Census in 2021, the largest number of farms are private households. Incidentally, the largest crop acreage belongs to agricultural enterprises – 52.4 million hectares. According to the results of the 2021 Census, peasant farms, and Individual entrepreneur farms owned 25.4 million hectares of crop acreage. Private households owned only 2.3 million crop acreage.

Figure 3.3.2. Structure of agricultural products by category of farms, 2015-2020, share %



Source: ROSSTAT, Agriculture in Russia, 2021

Agricultural Enterprises

Agricultural enterprises in the Russian Federation include business partnerships, companies and partnerships, production cooperatives, unitary enterprises, and subsidiary farms of non-agricultural organizations and institutions.

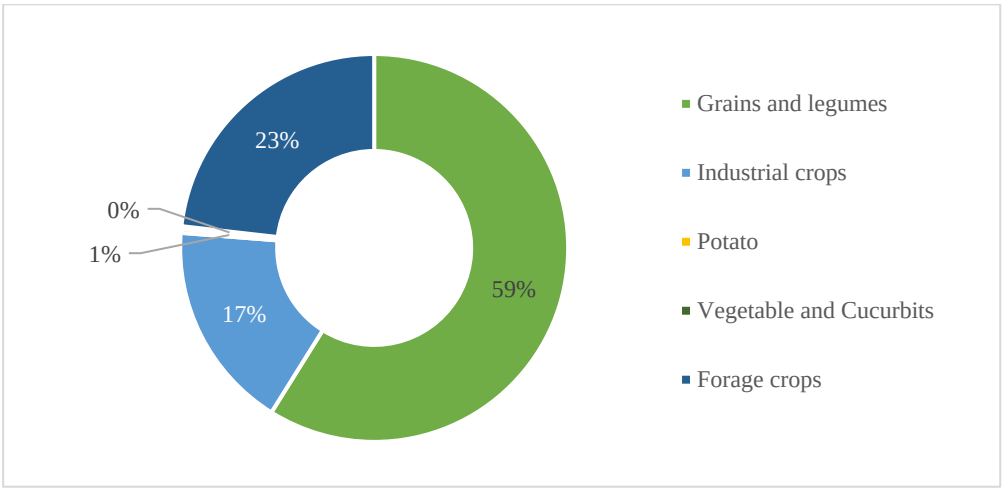
According to the results of the last All-Russia Agricultural Census 2021, there were 32.9 thousand agricultural enterprises. These enterprises occupied the largest share among all crop acreage in the Russian Federation, accounting for 60%.

Table 3.3.8. Crop acreage of Agricultural enterprises, 2016, 2021, thousand ha

Category of crops	**2016**	**2021**
Grains and legumes	32,161.8	30,179.9
Industrial crops	9,478	11,959.1
Potato	193.9	153
Vegetable and Cucurbits	109.4	102.6
Forage crops	12,672.9	10,023.3

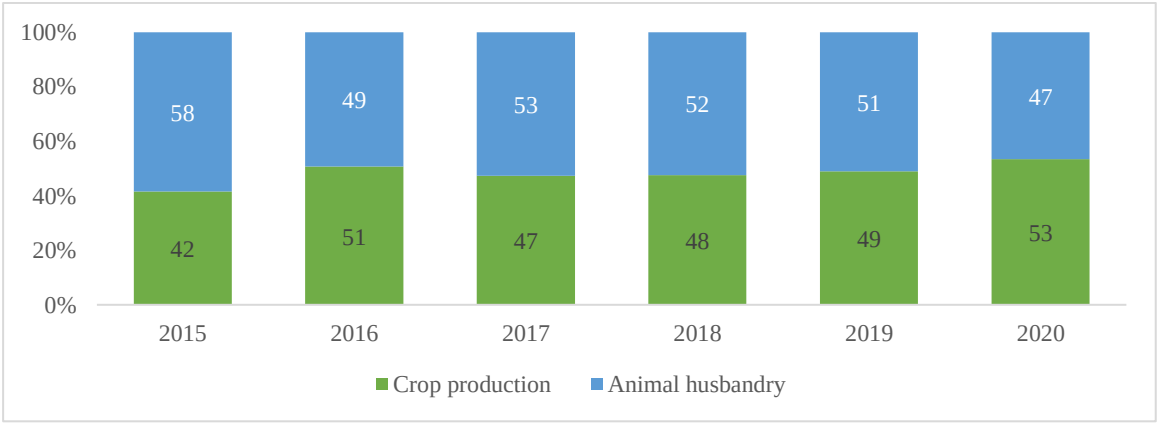
Source: All Russia Agricultural Census 2016, 2021

Figure 3.3.3. Structure of acreage by type of agricultural crops in Agricultural enterprises, 2021, share %



Source: All Russia Agricultural Census 2016, 2021

Figure 3.3.4. Specific weight of crop production and animal husbandry in agricultural products in Agricultural enterprises, 2015-2020, share %



Source: ROSSTAT, Agriculture in Russia, 2021

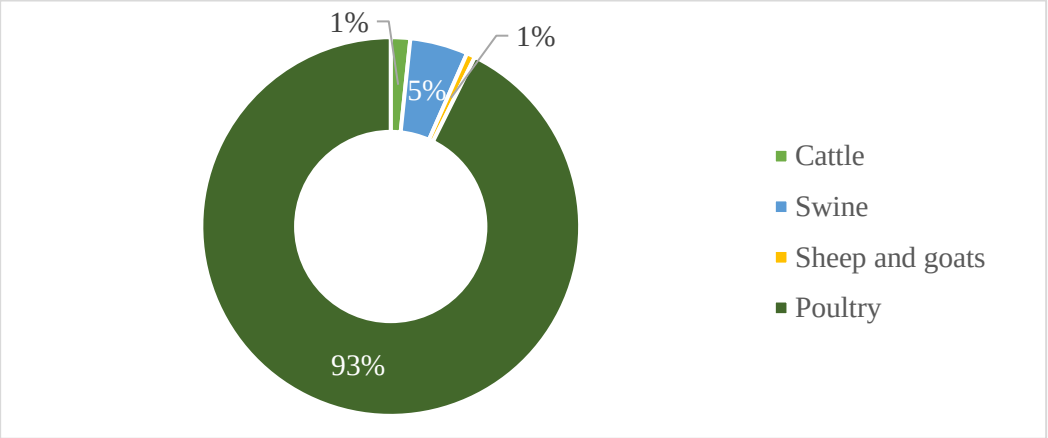
According to the ROSSTAT Statistics, crop production and animal husbandry prevail almost equally. Over the past six years, their prevalence has been constantly changing. At the end of 2020, the share of crop production was 53%, and the share of animal husbandry was 47% for agricultural enterprises (Figure 3.3.4.).

Table 3.3.9. Livestock of farm animals of Agricultural enterprises, 2016, 2021, thousand heads

Category of farm animals	**2016**	**2021**
Cattle	8,598.1	8,230.7
Swine	18,958.8	24,502.6
Sheep and goats	5,155.1	3,612.6
Poultry	434,365.1	459,360.1

Source: All Russia Agricultural Census 2016, 2021

Figure 3.3.5. Structure of farm animal by type in Agricultural enterprises, 2021, share %



Source: All Russia Agricultural Census 2021

The main farm animals that agricultural enterprises raise are poultry. According to the All Russia Agricultural Census, in 2021, the share of poultry in total farm animal quantity was 93%. The number of pigs was 5% of the total farm animals. The share of cattle, sheep and goats was 1%.

Table 3.3.10. Availability of agricultural organizations with tractors and combines in the Russian Federation, 2017 – 2021

Index of availability	**2017**	**2018**	**2019**	**2020**	**2021**
There are tractors per 1000 hectares of arable land, units	3	3	3	3	3
Arable land load per tractor, ha	328	337	345	349	363
Accounts for 1000 hectares of crops (planting) of the corresponding crops, pcs.:					
Combines					
Grain harvesters	2	2	2	2	2
Maize harvesters	0	0	0	0	0
Potato harvesters	17	15	15	15	14
Flex harvesters	11	11	10	9	13
Beet harvesters (without haulm harvesters)	2	2	2	2	2
It is necessary to sow (plant) the corresponding crops, ha:					
For one Combine					
Grain harvester	427	424	437	451	449
Maize harvester	2,625	2,366	2,772	2,974	2,808
Potato harvester	60	68	68	66	70
Flex harvester	93	89	100	114	79
Beet harvester (without haulm harvester)	465	456	478	431	479

Source: ROSSTAT

Peasant farms and Individual Entrepreneur Farms

Peasant farms are an association of citizens related by kinship and (or) property, who have property in joint ownership and jointly carry out production and other economic activities (production, processing, storage, transportation, and sale of agricultural products) based on their participation.

Individual entrepreneur farms are composed of citizens (individuals) engaged in entrepreneurial activities without forming a legal entity who is engaged in agriculture.

According to the last All Russia Agricultural Census 2021 results, there were 123.2 thousand farms. Peasant farms and individual entrepreneur farms occupied around 30% of total crop acreage in the Russian Federation.

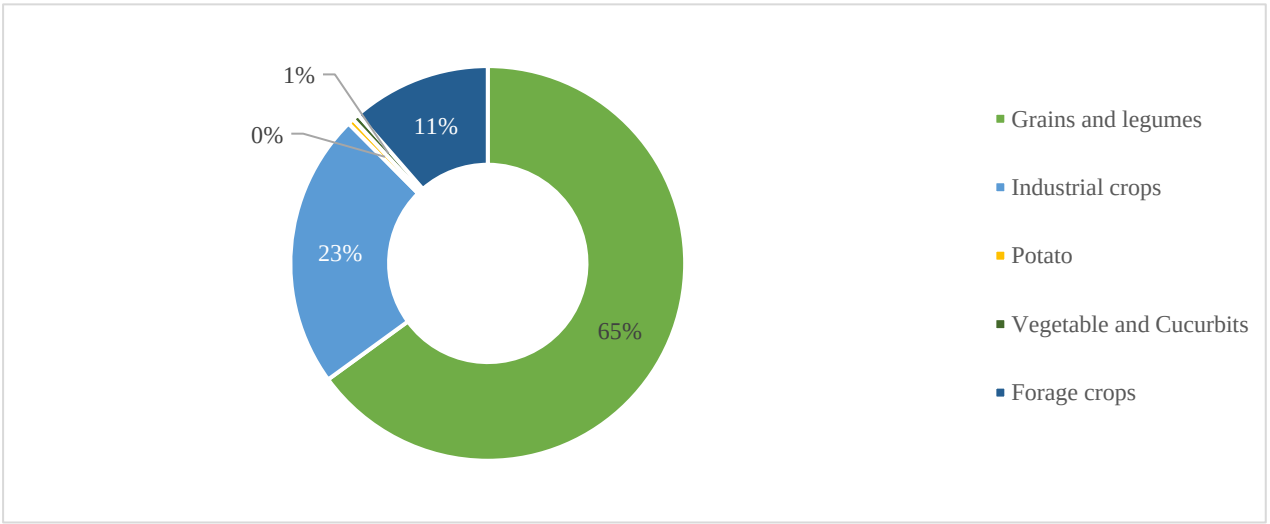
Table 3.3.11. Crop acreage of Peasant farms and Individual entrepreneur farms, 2016, 2021, thousand ha

Category of crops	2016	2021
Grains and legumes	17,782.4	16,484.2
Industrial crops	4,052.9	5,720.2
Potato	150,6	125,9
Vegetable and Cucurbits	174,0	138,2
Forage crops	2,842.4	2,894.7

Source: All Russia Agricultural Census 2016, 2021

The main crop grown in peasant farms and individual entrepreneur farms, according to the All Russia Agricultural Census 2021, were grains and legumes. They accounted for 65% of total crops in peasant farms and individual entrepreneurs' farms.

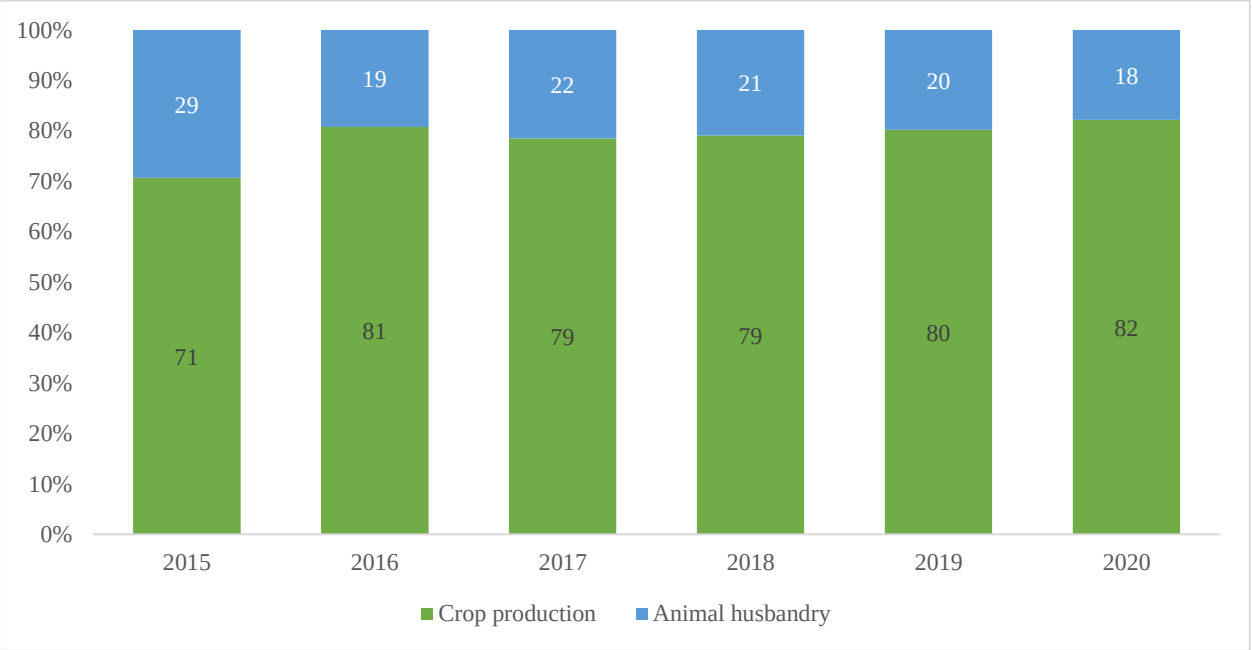
Figure 3.3.6. Structure of acreage by type of agricultural crops in peasant farms and individual entrepreneur farms, 2021, share %



Source: All Russia Agricultural Census 2021

According to the ROSSTAT Statistics, farmers from peasant farms and individual entrepreneur farms conducted crop production dominantly, accounting for 82% at the end of 2020, and the share of animal husbandry was 18% (Figure 3.3.7.). Farmers from peasant farms and individual entrepreneur farms specialized in growing grains and legumes.

Figure 3.3.7. Specific weight of crop production and animal husbandry in agricultural products in peasant farms and idividual entrepreneur farms, 2015-2020, share %



Source: ROSSTAT, Agriculture in Russia, 2021

Table 3.3.12. Livestock of farm animals of Peasant farms and Individual Entrepreneur farms, 2016, 2021, thousand heads

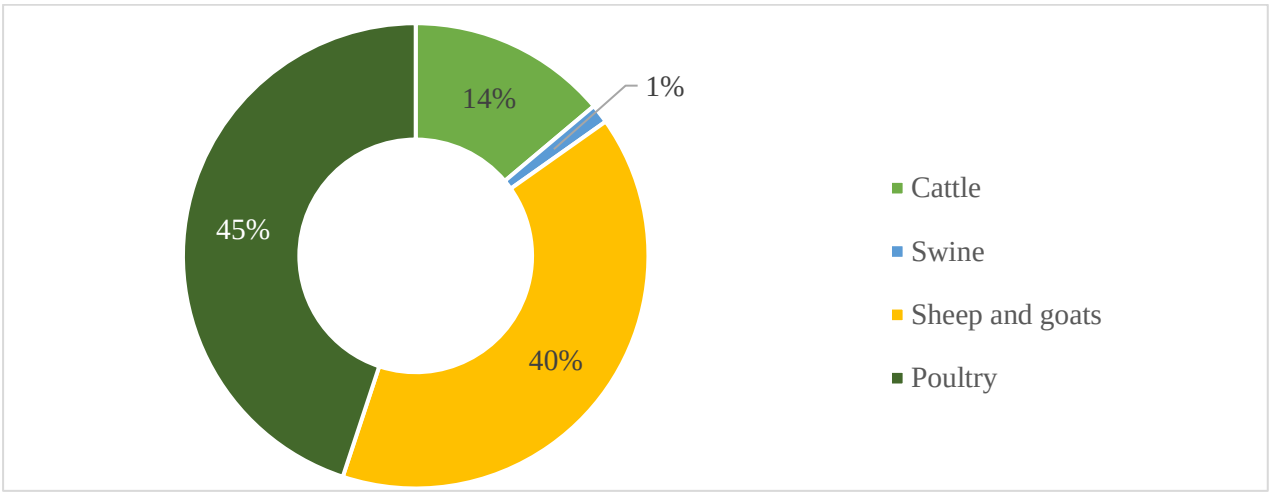
Category of farm animals	2016	2021
Cattle	2,564.3	3,056
Swine	497	293.5
Sheep and goats	9,772.8	8,785.1
Poultry	11,208.1	9,898.0

Source: All Russia Agricultural Census 2016, 2021

The main type of farm animals raised in peasant and individual entrepreneur farms is poultry. According to the All Russia Agricultural Census, in 2021, the share of poultry in total farm animal quantity was 45%. The number of sheep and goats was 40%, cattle share was 14%, and swine was 1%.

The structure of farm animals by type in peasant farms and individual entrepreneur farms differs from that of agricultural enterprises, where poultry occupies 93% of the total quantity of farm animals.

Figure 3.3.8. Structure of farm animal by type in Peasant farms and Individual entrepreneur farms, 2021, share %



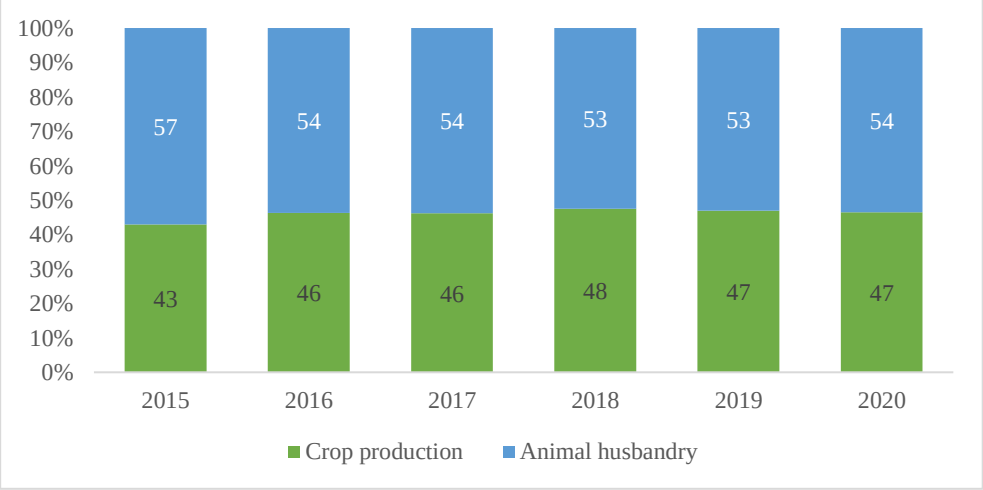
Source: All Russia Agricultural Census 2021

Private households

Private households include personal subsidiaries and other individual farms of citizens in rural and urban settlements and farms of citizens who have land plots in non-profit horticultural associations.

According to the results of the last All Russia Agricultural Census 2021, there were 2.3 million private households. They occupied around 10% of the total crop acreage in the Russian Federation.

Figure 3.3.9. Specific weight of crop production and animal husbandry in agricultural products in Private households, 2015-2020, share %



Source: ROSSTAT, Agriculture in Russia, 2021

According to the ROSSTAT Statistics, animal husbandry dominated 54% of the production share of private households at the end of 2020, and the share of animal husbandry was 47% (Figure 3.3.9.).

There is no additional information the structure of acreage by type of agricultural crop and the structure of farm animals for private households in the last All Russia Agricultural Census 2021.

Doctrine of Food Security of the Russian Federation

In the Russian Federation, there is a particular document, the Doctrine of Food Security of the Russian Federation, which presents a set of official views on the goals, objectives, and main directions of the state economic policy in ensuring the country's food security. A Decree of the President of the Russian Federation approves the document annually.

The Doctrine uses the indicator "Level of self-sufficiency" in the main types of agricultural products to obtain information on the level of provision with the main types of agricultural products. It is calculated as the ratio of the volume of domestic production of agricultural products, raw materials, and food to the volume of their domestic consumption. It has threshold values for the following types of agricultural products. The indicator is measured in percentages.

Table 3.3.13. Level of self-sufficiency in the main types of agricultural products, 2020, %

Type of agricultural product	Value, %
Grain	95
Sugar	90
Vegetable oil	90
Meat and meat products	85
Milk and dairy products	90
Fish and fish products	85
Potato	95
Vegetable and Cucurbits	90
Fruits and berries	60
Seeds of the main agricultural crops of domestic selection	75

Source: Doctrine of Food Security of the Russian Federation, 2021

Food independence is understood as the self-sufficiency of the country with the main types of domestic agricultural products, raw materials and foodstuffs, and the possibility of acquiring food products of proper quality at prevailing prices under the economic availability of food, in volumes and assortment that correspond to the recommended rational consumption standards. According to the Doctrine, the Russian Federation is provided with primary agricultural products.

Table 3.3.14. Availability of grain in procurement and processing organizations as of 1 January 2022, thousand tons

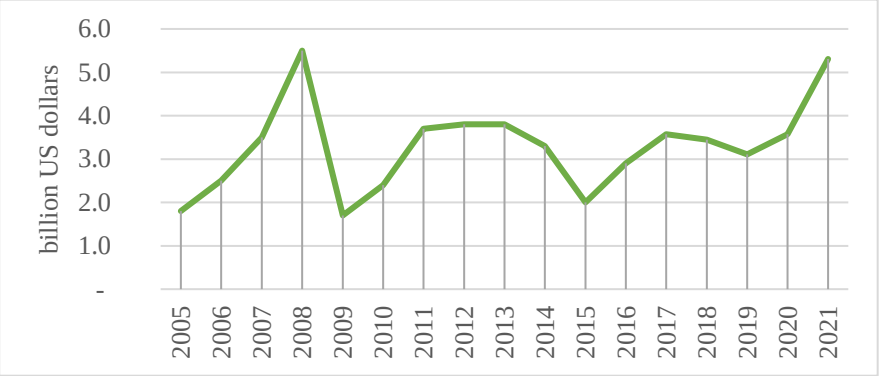
Grains and legumes	Wheat	Wheat suitable for food purposes	Barley	Corn	Oats
13,192.6	8,124.8	3,313.5	1,664.7	1,321.9	209.6

Source: FEDSTAT

4) Demand

The dynamics of demand for agricultural machinery depend on factors such as fluctuations in grain prices, financial crises, weather conditions (drought or flood), level of state support, leasing, quotas for export, and the renewal of the agricultural machinery fleet.

Figure 3.3.10. Market of agricultural machinery in the Russian Federation, 2005-2021, billion USD



Source: ROSSPETSMASH STAT

Figure 3.3.10 above shows a graph of changes in the market of agricultural machinery in the Russian Federation from 2005 to 2021. The graph highlights three periods of sales decline in 2009, 2014-2015, and 2018-2019.

The sharp decline in the market in 2009 and 2015 was due to the global financial crisis 2008 and the currency crisis in the Russian Federation in 2014-2015. Then, there was a decrease in demand for agricultural machinery in the country. The decline in the market in 2018 was due to a reduction in the production of agricultural machinery. However, compared with the recessions of 2009 and 2015, the decline in 2018 was insignificant, only 3%. For comparison, the decrease in 2009 was 70%, and in 2015 - 47%.

Currently, the main demand factors are grain prices and the State support programme for Russian agricultural machinery manufacturers (Programme №1432).

The programme of State subsidies for agricultural machinery manufacturers (State Programme No. 1432,) is a federal programme for subsidizing agricultural machinery manufacturers aimed at

supporting domestic agriculture and agricultural engineering. It had been implemented since 1 January 2013, as part of the implementation of the Decree of the Government of the Russian Federation No. 1432 released on 27 December 2012, titled "On approval of the rules for the provision of subsidies to manufacturers of agricultural machinery". In 2021, this discount under Programme 1432 was 10% (previously, 25-30%). In 2022, the discount for the purchase of agricultural machinery was 10% and 15% for remote regions of the Far East, Siberia, Kaliningrad, and other remote regions.

Table 3.3.15. Agricultural machinery sold through the Decree of the Government of the Russian Federation 1432

Agricultural equipment	**2017**	**2018**	**2019**	**2020**	**2021**
Thousand units	27.1	20.9	23.2	-	22.5
The total amount of subsidy given to producers under the Programme 1432					
billion rubs.	15.7	10.0	14.5	14.0	10.0
Million US dollars	269.1	159.5	224.0	194.0	135.8

Source: ROSSPETSMASH STAT, FEDSTAT

The State programme was launched in 2013, but it began to operate in 2016, when the constant growth of the agricultural machinery market began. According to ROSSPETSMASH data obtained from a survey of manufacturers in 2021, 22.5 thousand agricultural machines were sold through Programme 1432. The total subsidy given to producers under Programme 1432 in 2021 was 135.8 million US dollar.

Table 3.3.16. Agricultural machinery transferred to buyers under the Programme 1432, units

Type of machinery	**2021**
Agricultural machinery, total	22,449
including:	
Combine harvesters	4,083
Forage harvesters	190
Agricultural tractors	3,416
Other self-propelled machinery	899
Trailed, mounted, stationary and other agricultural machinery	13,861

Source: ROSSPETSMASH STAT

Preferential leasing is another measure of State support for demand for domestic agricultural machinery. The largest lessor is the Russian company ROSAGROLEASING (JSC), with 100% state stake in the established capital. The main activity of ROSAGROLEASING is the financial lease (leasing) of equipment and machinery to business entities (domestic agricultural

producers) operating in the field of the agro-industrial complex and its industries (residents of the Russian Federation). ROSAGROLEASING offers leasing agricultural machinery on favorable terms with an average annual appreciation of 3%.

Table 3.3.17. The number of agricultural equipment sold through the preferential leasing programme of ROSAGROLEASING (JSC)

Thousand units	**2019**	**2020**	**2021**
Agricultural machinery	7.2	9.7	10.21
including:			
Agricultural tractors	-	1.87	1.56
Combines	-	1.55	1.35
Other agricultural machinery	-	6.28	7.3
In the amount of, million rubles	**27,823.4**	**44,652.8**	**-**

Source: National Report on the Implementation of the State Program for the Development of Agriculture and Regulation of Agricultural Products, Raw Materials, and Food Markets

According to the National Report on the implementation of the State Program for the Development of Agriculture and Regulation of Agricultural Products, Raw Materials, and Food Markets in 2021, the number of agricultural equipment sold through the preferential leasing programme of ROSAGROLEASING (JSC) was 10.21 thousand pieces.

5) Supply Chain

There are two ways of product and service flow from producers to end-user: dealer system and resale.

Dealer system is the official sales representative of the manufacturers. Agricultural machinery producers either have their own dealer network or use the services of large multi-brand dealer centers. The distribution centers' main tasks are to sell machinery and equipment, spare parts, and provide pertinent services to their customers.

For example, the largest Russian manufacturers of agricultural machinery, such as ROSTSELMASH and KIROVETS (Petersburg Tractor Plant), have created their dealer network with dealer centers worldwide. They carry out the business of selling machinery and equipment as well as spare parts and providing maintenance services for the sold products.

Smaller manufacturers use the services of large federal and regional multi-brand dealer centers. Several large dealers in the agricultural machinery market are engaged in the purchase and sale of agricultural machinery, mounted and trailed equipment (seeders, harrows, plows, mowers, etc.). They also provide services for the repair and replacement of sold goods and the delivery of agricultural machinery for rent or leasing.

Russian manufacturers of agricultural machinery use the following promotion methods to promote their products to end users:

- Sales department of dealer system;
- Federal and regional field days;
- Federal and regional agricultural machinery exhibition.

The second way is resale. Resales are carried out by organizations that are not official dealers. They buy machinery and equipment from manufacturers and resell it to the end users. Such sales centers are also engaged in the sale of spare parts and provide related services.

Field Day

Field Day is a large-scale exhibition of advanced agricultural technologies demonstrated in real field conditions. The event presents a wide range of modern agricultural machinery and equipment, fertilizers, and plant protection products, the latest achievements in crop breeding.

In 2022, the Ministry of Agriculture of the Russian Federation decided to hold the event not only in the traditional format but also online, to increase its coverage and introduce the latest developments in the domestic agro-industrial complex to a broader audience, as well as take a fresh look at solving issues of agricultural development, agricultural science and technology.

Agricultural exhibitions

Another important way of promoting agricultural machinery by Russian manufacturers is participation in various specialized exhibitions. At exhibitions, manufacturers can demonstrate their latest developments to potential buyers. In the Russian Federation, exhibitions are divided into two types: federal and regional.

The largest federal exhibition in the Russian Federation is the international exhibition of agricultural machinery **AGROSALON**. It is the main specialized event in the Russian Federation to demonstrate innovative technology and technological solutions in the agro-industrial complex. The exhibition is grand scale and presents the whole range of machinery, components, and equipment for the work in the field from global manufacturers. It is carried out by the largest professional associations of agricultural machine builders in the Russian Federation and Germany - the ROSSPETSMASH and VDMA Landtecknik Associations.

The second large agricultural equipment show is **Golden Autumn**. The specialized exhibition of agricultural machinery and equipment AgroTech Russia is usually held as part of the Golden Autumn exhibition. Visitors to the exhibition can get acquainted with a variety of models of agricultural machinery and related equipment presented by exhibitors from the Russian Federation and 12 other countries of the world - equipment for fertilizing and plant protection, for harvesting grain and fodder, machines for land reclamation and for the cultivation and harvesting of potatoes, sugar beet, and other vegetables. For specialists and heads of enterprises, the competitive programme is an integral part of the exhibition. Gold, silver, and bronze medals are granted to the winners of the competitive programme, which is the best evidence of the professionalism of domestic agricultural producers and the high quality of their work.

The largest regional trade show is YugAgro. Every year, YugAgro showcases over 640 Russian and

international exhibitors, representing the products, including agricultural machinery, equipment and materials for crop production. In 2021, the event attracted 14,381 visitors from 73 Russian regions and 47 countries looking for new products and services for their businesses.

As a rule, all machinery and equipment are purchased by end users either at their own expense or at the expense of various financial instruments, such as leasing and lending (preferential and commercial).

Leasing and lending (preferential and commercial) are carried out by the largest Russian banks with a low-interest rate of around 5%. This is supported by the Ministry of Agriculture of the Russian Federation.

The largest lessor is ROSAGROLEASING (JSC). Other large Russian banks also carry out leasing.

6) Sustainability

Over the past ten years, the number of rural residents and settlements has decreased in the country. This was influenced by many factors: a decrease in the birth rate, high mortality and lower life expectancy compared to the cities, but most of all, the migration of rural residents to more favorable regions of the country. There is a clear geographical direction of migration - the outflow goes to the central and western regions of the country. The main migration destinations of rural residents are the Moscow and Leningrad regions.

Unemployment in the countryside is much higher than in the city, which makes the low incomes of the villagers even lower. Only those who are employed in the agro-industrial complex have high wages. The number of such workers is not many, which is also declining due to the intensification of production. For example, due to the use of robotic milking systems in livestock, grape harvesters, and mechanized pruning of fruit trees in horticulture, the requirement of labor in the agro-industrial complex is declining, while the qualification requirements for employees are increasing.

The solution to these problems can be the federal programme "Integrated Development of Rural Territories". Currently, this programme is the main tool for the development of rural areas in the Russian Federation with unprecedented government funding. Under the terms of this programme, the Ministry of Agriculture of the Russian Federation provides funds on the terms of co-financing from regional and local authorities. The main goals of the State programme are to maintain the share of the rural population in the total population of the Russian Federation at a level of at least 25.3%, to achieve the food self-sufficiency ratio of the average monthly disposable resources of rural (for example, arable and other agricultural land) and urban (such as infrastructure) households to 80%, and to increase the share of the total area of comfortable living quarters in rural areas to 50%.

The number of people employed in agriculture, according to ROSSTAT statistics, at the end of 2020 amounted to 401.2 million people, which accounted for 5.8% of the total employed population in the Russian Federation (Federal State Statistic (ROSSTAT). In 2019, the share of

women in agriculture was 44% of the total population in agricultural employment. (Federal State Statistic (ROSSTAT). The role of women in agriculture started to rise during the USSR period.

In 1995, the All-Russian Social Movement of Rural Women of Russia was created on the basis of the Association of Peasant (Farmer) Farms and Agricultural Cooperatives of Russia (AKKOR). Now, the movement includes more than 30 regional branches. The main goals of the All-Russian Social Movement of Rural Women of Russia are the development of civic activism of rural women; assistance in creating legal, social, and economic conditions for improving the living standard of women in rural areas; participation in social policy in rural areas aimed at improving working and living conditions of women, protecting the rights of motherhood and childhood; assistance to rural families in the issue of land relations; support for youth in rural areas and development of agricultural education; promotion of infrastructure development in rural areas and many others.

Today, women in rural areas are playing the leading role in almost every third of agricultural enterprises; women hold 30% of municipal positions, and women are leaders of a third of rural settlements. One in four family livestock complexes are headed by women, and among the novice farmers who have received grants from the State over the past three years, women make up almost a third.

In the Russian Federation, the non-profit partnership "National Movement of Conservation Agriculture" was created in 2003 to spread knowledge on technologies of soil-protective and resource-saving agriculture, contributing to reducing the negative impact on the climate and improving product quality, as well as stimulating research on these technologies for widespread use. Partners of the Movement are agricultural machinery enterprises, producers of seeds, agricultural products and mineral fertilizers, agricultural universities, large agricultural holdings, agricultural departments, agricultural firms, farms, and agricultural specialists throughout the country. The National Movement of Conservation Agriculture is also a member of the European Federation of Conservation Agriculture (ECAF), and a partner of such major international organizations as Aapressid and FAO. The Movement has accumulated a large information base, including materials, including those translated independently, on advanced foreign and domestic experience in agriculture, which is constantly updated and is accessible to all participants of the Movement. In addition, the National Movement of Conservation Agriculture issued several brochures and methodological recommendations to facilitate and accelerate the transition to resource-saving technologies. The National Movement of Conservation Agriculture publishes the journal "Resource-saving Agriculture" – the first specialized publication in the Russian Federation dedicated to resource-saving technologies, where materials on Russian and foreign experience in their application are published, and also maintains the Agroecommission platform – the first Internet resource in the Russian Federation on technologies of soil-protecting and resource-saving agriculture - in order to promote modern technologies in agriculture.

Agricultural production is more dependent on weather conditions than any other type of activity, so insurance for this type of business is particularly relevant for entrepreneurs. Agricultural insurance mitigates the consequences for entrepreneurs after natural disasters, which can result in crop or livestock losses. The Federal Law "On the Development of Agriculture" regulates agricultural insurance at the State level. The objects of insurance for agricultural enterprises include the property interests of the insured related to the risk of loss of crops, livestock, and property. This is especially true for risk farming areas such as the territories where effective farming is difficult due to the climatic conditions. Most of the territory of the country is in risk farming areas, except the southern regions of the European part of the Russian Federation. The agricultural insurance safeguards the benefits of farmers and the development of agriculture, which ensures the sustainability of agricultural mechanization in the Russian Federation.

The table below shows the statistics for agricultural machinery's share over ten years. Farmers still lack modern and high-performance digitalized equipment. The share of grain harvesters older than ten years is 59%, forage harvesters - 60%, and tractors - 68%. Thus, upgrading old and outdated machines and equipment shall be managed strategically.

Table 3.3.18. Main types of equipment, from the date of issue of which more than 10 years have passed, in the Russian Federation, 2019-2020, %

Type of equipment	2019	2020
Tractors	74	68
Combines	66	59
Foragers	66	60

Source: National Report on the Implementation of the State Program for the Development of Agriculture and Regulation of Agricultural Products, Raw Materials, and Food Markets.

In the last decade, we have seen the rise of robotics. This industry captures all spheres of human activity. Robotization can minimize the environmental burden of agriculture by designing robotic devices that ensure the transition from traditional heavy special equipment to mass-produced, lightweight, multi-agent, energy-efficient, resource-saving technologies. The cost of robots is high at this moment, but its mass introduction will presumably lead to a significant reduction in price due to the economy of scale. Robots are becoming more versatile and less costly to manufacture, which will lead to replacing low-skilled labor with robots. At the same time, the development of robots requires highly skilled labor. Therefore, human resource development is also an important factor in the sustainable development of agricultural mechanization.

Thus, in the Russian Federation, to ensure the sustainability of agricultural mechanization, efforts shall be made and are being made to increase the rural population, enhance rural women’s benefits, better preserve agroecology

through, for example, conservation agriculture, and ensure the development of cutting-edge technologies.

7) Conclusions

The Russian Federation has a unique agricultural potential - it is one of the world's largest grain-producing and grain-processing regions, with 9% of the world's arable land. The Russian Federation is currently the world's largest producer of barley, ranks second in the production of sunflower seeds, third in the production of potatoes and milk, and fourth in the production of wheat. In recent years, the Russian Federation became the largest exporter of wheat and of these crops. According to the Doctrine of Food Security of the Russian Federation, the country is fully provided with essential agricultural products.

The Russian Federation produces a full range of agricultural equipment, from soil processing equipment to machinery for harvesting and storage. The share of Russian manufacturers in the Russian agricultural machinery market was 61%. The main types of agricultural machinery produced in the Russian Federation are harvesting machinery, including grain and forage harvesters, tillage and seeding machines, and tractors.

The government of the Russian Federation actively supports the agricultural sector by providing various subsidies to agricultural machinery manufacturers and farmers. One of the main government support programmes in the agricultural sector is the federal programme for subsidizing agricultural machinery manufacturers, aimed at supporting domestic agriculture and agricultural machinery engineering - the programme of State subsidies for agricultural machinery manufacturers (State Programme No. 1432). Preferential leasing is an essential measure of state support for the demand for domestic agricultural machinery for farms. The largest lessor is the Russian company ROSAGROLEASING (JSC), with 100% State stake in the established capital. Another measure of government support for the agricultural sector is agricultural insurance, which covers crops, livestock, and property of farmers.

To address the issue of the decline of rural residents and settlements, the government has developed the federal programme "Integrated Development of Rural Areas."
The All-Russian Public Movement of Rural Women reflect the gradual increase of the share of women employed in agriculture. The members of this movement include women representing farms and agricultural cooperatives, as well as owners of personal subsidiary farms. The main goal of this movement is to improve the rights of women in rural areas and more so in agriculture.

The development of conservation agriculture holds a vital place in the sustainable development of agriculture in Russia. In order to promote the goals and objectives of conservation agriculture in Russia, the Non-Profit Partnership "National Conservation Agriculture Movement" has been created.

Thus, agriculture and agricultural machinery engineering in the Russian Federation are fairly high. The government is actively supporting the

development of this sector of the economy. However, much more remains to be done to modernize the agro-industrial complex. After all, qualified and sufficient equipment and facilities allow us to increase productivity, reduce costs, develop new lands, and ensure maximum use of land resources.

8) Recommendations

The share of agricultural machinery older than ten years exceeds 50% (the situation is slightly better for combine harvesters than for tractors). To reverse the situation, it is necessary to increase the purchase of new equipment by 1.5-2 times and maintain this renewal process for three to five years. Due to the lack of machines, farmers often work beyond the optimal time frame, significantly reducing product yield and quality. There is also a lack of production capacities for self-propelled vehicles by the domestic manufacturers. Thus, for equipment renewal, state support measures are needed to stimulate the end users' purchase of new equipment.

Introducing new technologies in agriculture requires the capacity building of engineering personnel based on modern knowledge. Achieving this, it is necessary to create new courses, work programmes, and practices for the regions robotization, maintenance and repair services.

In the Russian Federation, there are several measures of state support for the purchase of agricultural machinery by farmers, for example, the government decree No. 1432, preferential leasing, mechanisms for subsidizing the transportation of products, compensation for part of the costs of R&D, preferential loans, besides a number of other measures. For the further development of the production of agricultural machinery in the Russian Federation and the growth of the pace of technical modernization of the agro-industrial complex, it is necessary to maintain these support measures, laying down the required amount of funding for the coming years.

D. Viet Nam Country Market

1) Agricultural Profile, brief overview

Viet Nam has a total land area of 33,123,300 hectares, of which 27,289,400 hectares (about 82%) are used for agricultural purposes. The area for rice cultivation is 4,120,500 hectares, for other annual crops is 2,831,600 hectares, and for perennial crops is 4,546,400 hectares.

The Government of Viet Nam has been vigorously promoting the process of agricultural restructuring towards the production of value-added products and sustainable development along with the formation of large, specialized farming areas the application of high technology and clean technology. Mechanization and automation are therefore encouraged.

The Government has been strengthening measures to control the quality of imported machinery and equipment to ensure that their technical features are consistent with the level of advanced, modern, and environment-friendly technologies.

Viet Nam's agriculture continues implementing the policy of restructuring crops on land inefficient rice and actively converting the planting areas without a balance of water sources to growing vegetables, crops, and fruit trees or combining with aquaculture with higher economic efficiency. At the same time, the sector increases the use of high-quality seeds and organizes production according to the model of 'big field' not only for rice but also for other crops, and promotes the application of production according to the Viet GAP process or equivalent.

According to the report on Implementation results of the development plan for agriculture and rural areas, in the 2016-2020 period, the average annual growth rate of gross domestic product (GDP) in the fields of agriculture, forestry, and fishery reached 2.71%. In 2020, the COVID-19 pandemic affected production and export, import, and consumption activities. In addition, agricultural production including forestry and fishery, faced many other difficulties due to drought, saltwater intrusion, and floods. However, many efforts were made, and agricultural GDP in 2020 still reached 2.8% (higher than the growth rate of 2.41% in 2015).

Some information on the production of main crops in recent years (rice and other food crops, fruit and vegetables, and perennial industrial crops) is presented as follows:

(i) Land uses for different crops and areas

Table 3.4.1. Land use (as of 31 December 2018)

Unit: Thousand ha

	Total areas	of which	
		Land allocated for users	Land allocated for managers
Whole country	**33,123.6**	**26,842.8**	**6,280.8**

Agricultural land	**27,289.4**	**24,456.6**	**2,832.8**
- Agricultural production land	11,498.5	11,383.8	114.7
Annual crop land	6,952.1	6,890.7	61.4
Paddy land	4,120.5	4,102.5	18.0
Other annual crop land	2,831.6	2,788.2	43.4
Perennial crop land	4,546.4	4,493.1	53.3
- Forestry land	14,940.8	12,230.7	2,710.1
- Water surface land for fishing	795.3	788.1	7.2
- Land for salt production	17.0	16.5	0.5
- Others	37.8	37.5	0.3

Source: Office of General Statistics (2020)

Table 3.4.2. Planted area of main crops

Unit: Thousand ha

Year	Paddy	Maize	Sugarcane	Cotton	Peanut	Soybean
2016	7,737.1	1,152.7	267.6	0.5	184.8	99.6
2017	7,705.2	1,099.5	281.0	0.4	195.6	68.4
2018	7,570.9	1,032.9	269.3	0.2	185.7	53.3
2019	7,469.5	986.7	237.9	0.2	176.8	49.4
Prel.2020	7,279.0	942.5	185.7	0.1	169.7	41.6

Source: Office of General Statistics (2020)

The area for rice cultivation in recent years has tended to decrease gradually to transform the crop structure in the direction of improving quality and efficiency. Rice cultivation area in 2020 reached 7,279 thousand hectares, decreasing 190.5 thousand hectares compared to 2019.

Table 3.4.3. Planted area of main perennial crops

Unit: Thousand ha

	2016	2017	2018	2019	Prel.2020
Fruit crops					
Grape	1.3	1.3	1.4	1.3	1.3
Mango	74.6	92.7	99.8	104.9	111.6
Orange, mandarin	65.1	112.6	120.8	120.3	117.1
Longan	63.9	75.7	78.7	80.6	80.2
Litchi, rambutan	83.2	84.4	82.6	79.3	75.2
Perennial industrial crops					
Cashew	281.0	297.5	299.5	297.0	302.4
Rubber	621.4	971.6	961.8	941.8	932.4

Coffee	597.6	664.6	680.7	690.1	695.6
Tea	118.7	129.3	123.0	123.2	121.3
Pepper	81.8	152.0	147.5	140.2	131.8

Source: Office of General Statistics (2016, 2020)

The area for perennial crops in 2020 was estimated at 3,607.8 thousand ha, up 1.6% compared to 2019, including industrial plants reaching 2,179.9 thousand ha, down 0.6%; the group of fruit trees reached 1,133.8 thousand ha, up 6.2%; the group of oil crops reached 183.1 thousand ha, up 2.5%; the group of spices and medicinal plants reached 52.3 thousand ha, up 2.7%; the group of other perennial plants reached 58.7 thousand ha, decreased 5%. In the group of industrial plants and rubber, the area reached 932.4 thousand hectares, decreased 1% compared to the previous year, and the output reached 1,221.6 thousand tons, up 3.3%; the pepper area reached 131.8 thousand hectares, decreased 6%, output reached 268.5 thousand tons, up 1.4%; and the coffee area reached 695.5 thousand ha, up 0.8%, output reached 1,742.8 thousand tons, up 3.3%.

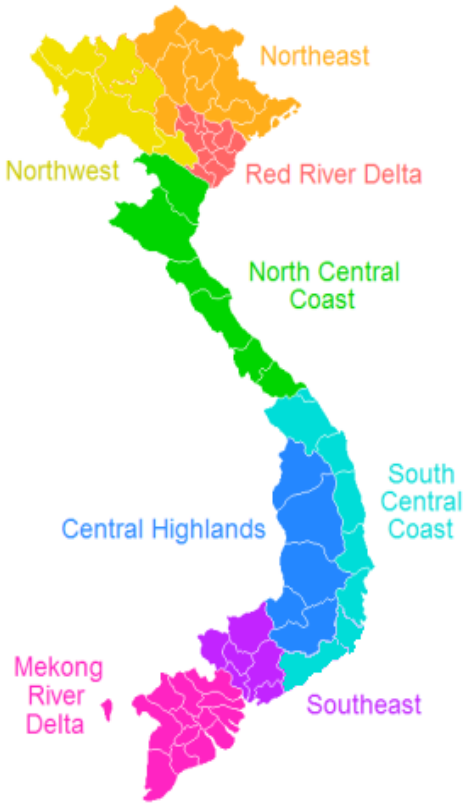
Table 3.4.4. Planted area of paddy by areas

Unit: Thousand ha

	2016	**2017**	**2018**	**2019**	**Prel. 2020**
Whole country	**7,737.1**	**7,705.2**	**7,570.9**	**7,469.5**	**7,279.0**
Red River Delta	1,094.4	1,071.4	1,040.8	1,012.3	983.4
Northern midlands and mountain areas	682.6	679.8	672.4	669.0	665.1
North Central and Central coastal areas	1,215.3	1,253.4	1,234.4	1,208.2	1,157.9
Central Highland	233.3	243.4	245.6	243.7	246.9
South East	270.4	271.9	270.2	267.4	262.0
Mekong River Delta	4,241.1	4,185.3	4,107.5	4,068.9	3,963.7

Source: Office of General Statistics (2016, 2020)

Figure 3.4.1. Socio-economic regions in Viet Nam



(ii). Production of some main crops

Table 3.4.5. Production of main annual crops

Unit: Thousand tons

Year	Paddy	Maize	Sugarcane	Cotton	Peanut	Soybean
2016	43,165.1	5,246.5	17,211.2	0.6	427.2	160.7
2017	42,738.9	5,109.6	18,356.4	0.4	459.6	101.7
2018	44,046.0	4,874.1	17,945.5	0.1	457.3	80.8
2019	43,495.4	4,731.9	15,685.6	0.1	442.6	77.3
Prel.2020	42,760.9	4,559.7	11,534.5	0.1	425.4	65.4

Source: Office of General Statistics (2020)

Maize production in 2020 reached 4,559.7 thousand tons, decreased 172.2 thousand tons compared to 2019 due to a decrease of 44 thousand hectares of cultivated area; sugarcane reached 11.5 million tons, decreased 3.44 million tons (area reduced by 45.3 thousand hectares); peanuts reached 425.4 thousand tons, decreased 17.2 thousand tons (area reduced by 7.1 thousand hectares); and, soybean reached 65.4 thousand tons, down 11.9 thousand tons (area reduced by 7.8 thousand hectares).

(iii). Exports of some main crops

Table 3.4.6. Agro-forestry-fishery export results, Unit: Million USD

	2016	2017	2018	2019	2020
Total export turnover	**32,087**	**32,700**	**39,217**	**40,209**	**41,250**
Agricultural products	**17,853**	**18,400**	**19,503**	**18,631**	**18,491**
Rice	2,192	2,600	3,094	2,806	3,069
Coffee	3,355	3,370	3,536	2,862	2,658
Rubber	1,670	1,730	2,091	2,301	2,382
Tea	223	230	207	236	220
Cashew	2,840	2,870	3,364	3,288	3,188
Pepper	1,421	1,450	759	714	666
Vegetables and fruits	2,416	2,500	3,806	3,745	3,259
Cassava and cassava Products	994	1,050	958	966	989
Other products	2,743	2,600	1,288	2,278	-
Forest products and furniture	**7,246**	**7,200**	**9,383**	**11,313**	**13,173**
Aquatic products	**6,988**	**7,100**	**8,401**	**8,542**	**8,384**
Husbandry products	**-**	**-**	**642**	**400**	**327**
Total import turnover	**-**	**-**	**31,401**	**30,870**	**30,957**

Source: MARD (2016-2020)

2) Agricultural Mechanization

(i) Some advantages for development of agricultural mechanization

Viet Nam's agriculture and rural areas have undergone substantial changes in recent years, which have significantly affected agricultural mechanization. Some of the most noticeable transformations are as followings:

- Industrialization and urbanization promote a movement of laborers from agriculture to industry and service sectors, resulting in a labor shortage in agriculture and necessitating greater mechanization.
- The movements of new rural construction, land consolidation, and large-scale field development reinforce the transportation and irrigation infrastructure system, thus increasing plot sizes and facilitating the production of agricultural machines, especially those with high capacities.
- As agricultural production and rural businesses increase, so does the farmers' income, allowing them to save substantial money to invest in mechanization.

Because of the advantages described above, the number of agricultural machines and equipment produced and used increased dramatically.

According to the Department of Economic Cooperation and Rural Development (Ministry of Agriculture and Rural Development), for the whole country, the number of prime movers and agricultural machines in 2020 compared to 2014 had increased, such as: tractors increased by 32.5% (of which large (≥ 35 hp) increased by 18.5%, mid-sized (12-35 hp) by 27.5% and small (≤

12 hp) by 38.7%), combine harvesters by 19.5% and agricultural dryers by 16.4%. Particularly, some types of machines had very fast growth rates, such as animal feed processing machines which increased by 134.9%, and pesticide spraying machines which nearly tripled (Table 3.4.7).

Table 3.4.7. Number of agricultural machines by the end of 2020

No.	Type of machines	Quantity by 2014	Quantity by 2018	Quantity by 2020
1	Total tractors	395,658	600,718	796,186
	- Large tractors (≥ 35 hp)	24,380	27,182	32,200
	- Mid-size tractors (12 - 35 hp)	105,180	282,763	360,600
	- Small tractors (≤ 12 hp)	266,098	290,773	403,386
2	Sowing machines	-	49,836	55,000
3	Rice transplanters	100	2,410	4,362
4	Combined harvesters	989	22,423	26,800
5	Combined sugarcane harvesters	-	-	12
6	Agricultural product kilns/dryers	7,352	68,841	80,100
7	Animal feed processing machines	38,264	58,405	137,200
8	Aquatic food processing machines	10,549	-	14,200
9	Water pumps	1,887,996		3,550,000
10	Pesticide spraying equipment	101,246	713,927	2,100,000

Source: DCRD (2021)

Recently, the average farm power availability has been estimated to be around 3.3 HP/ha of cultivated land across the country. For engines and tractors, the domestic mechanical industry has produced diesel engines with a capacity of up to 50 HP, accounting for over 30% of the domestic market share. For rice harvesters, the domestic industry captured only 15% of the market share. Domestic tractor brands are quite limited compared to foreign brands and only account for about 30% of the market share. The tractors (under 30 HP) are mostly produced by Vietnam Engine and Agricultural Machinery Corporation (VEAM) and account for 25% of the market share. In addition, recently, Truong Hai Group Joint Stock Company (THACO) has successfully produced tractors with a capacity of up to 50 HP. Southern Agricultural Machinery and Engine One Member Limited Liability Company has been developing 36-38 HP diesel engines.

The agriculture sector of Viet Nam has set a target that by 2030, the degree of mechanization of all stages of agricultural production will reach 80-100%, and the average farm power availability of the whole country will reach 5-6 HP/ha. In agricultural commodity production areas, the level of mechanization is expected to be synchronized and moved towards more automation.

According to the Ministry of Agriculture and Rural Development's forecast, the demand for tractors

and agricultural machines will increase from now to 2025. Specifically, on average, rice transplanters will increase rapidly from 500-1,000 units/year (6-8 row transplanter) synchronized with tray plating production technology. Combine harvesters for rice (with a working width of 1.8-2m) will increase from 2,000-3,000 units/year, mainly concentrating in the Mekong Delta, Red River Delta, Central Coast, and some other rice concentrated producing provinces. The demand for machines for harvesting sugarcane, coffee, corn, beans, and peanuts is 3-5 times higher than that of 2022.

(ii) Mechanization for crop production

Mechanization increases following a modern and synchronous trend in all stages of agricultural production.

a) Mechanization for rice production:

Viet Nam currently has 7.8 million hectares of arable land, of which rice land accounts for 4.1 million hectares, equivalent to 52.5 percent. Rice production has been mechanized in nearly all stages. However, machines used have many disadvantages, such as consuming a lot of energy. Table 3.4.8 shows rates of mechanization in different stages of rice production.

Table 3.4.8. Average mechanization rates for rice production stages from 2008 to 2020

Average mechanization rates by stage (%)	**Year**						
	2008	**2010**	**2012**	**2013**	**2017**	**2019**	**2020**
Soil preparation	75	85	88	90	93	95	97
Sowing and transplanting	5	8	10	18	25	45	65
Crop care and protection	55	58	60	65	75	80	82
Harvesting	15	23	35	42	50	70	78

Source: DCRD (2021)

Field construction and improvement stage: Ditching, embanking, leveling, and dredging canals have all been done with machinery. To date, many places have successfully used laser-controlled flattening machines.

Soil preparation stage: Mechanization increased from 75% in 2008 to 97% in 2020 on average, encompassing around 100% in the Mekong and Red River Deltas, and 70% in the Northern Midlands and Mountains.

Sowing stage: In 2008, just around 5% of rice was planted and transplanted by machine. By 2020, that percentage had risen to almost 65%, with the Mekong River Delta accounting for around 76% and the Red River Delta accounting for nearly 70%. The South Central Coast has the lowest percentage, around 54%.

Common types of transplanting machines on the market are 6 to 8 rows. Domestically produced machines are hand push rice transplanters (2 rows), HAMCO rice transplanters and Van Lang rice transplanters. Imported machines include Kubota and Yanmar rice transplanters. In addition to transplanting machines, farmers also use row

or swing sowing machines.

Crop care and protection stage: In 2008, the rate of mechanization in rice care and spraying of crop protection chemicals was only 55%, but by 2020 it had grown to 80%. Some provinces in the Mekong Delta and the North have used drones to spray crop protection chemicals and sow seeds.

Harvest stage: Mechanization for rice harvesting has risen dramatically, from 15% in 2008 to 78% in 2020. The Mekong Delta region has the highest amount of rice harvesting mechanization, at 92%, followed by the Southeast region at 77%, and the Northern Midlands and Mountains at 60%.

Straw collection stage: Mechanization for straw gathering has drastically increased in the southern provinces, particularly in the Mekong Delta, with a current rate of 90% using self-propelled and tractor-operated straw rolling machines.

b) Mechanization for other crops' production:

Sugarcane production: Approximately 200,000 hectares of sugarcane are currently planted. In sugarcane production areas, mechanization of land preparation has been achieved over 90%; planting has reached over 40%; and care and fertilizing has reached around 70%.

Maize production: Maize is grown on around 1.2 million hectares. In concentrated production areas, soil preparation, seeding, and tending stages are mechanized to about 70%. The harvesting stage has a modest amount of mechanization, about 5%. Mechanization is nearly 100% in areas where maize is cultivated as a green feed for cows.

Tea production: Tea production covers approximately 130,000 hectares. Around 70% of caring, weeding, and insecticide spraying operations are mechanized, while 40% of tea tree pruning and picking are done using machines.

Coffee production: Coffee-growing areas exceed 700,000 hectares. The stages of irrigation and care have reached around 90% of mechanization, and the harvesting stage has begun to employ a number of machines.

Specialized vegetables and flower production: Mechanization of soil preparation and irrigation is nearly 90%, while harvesting is done manually. Almost all areas of specialized vegetables and flower production apply high-tech models such as greenhouses and net houses. These houses apply economical irrigation, automatic regulation of temperature, humidity, and light, and are controlled for their operation via mobile phones.

c) Mechanization for animal husbandry

Mechanization of chicken coops in all stages, from water supplying, automatic feeding, microclimate creation, and egg collection, is in a high degree of mechanization, reaching over 90%. In addition, treating the breeding environment is 55% mechanized on average. Breeding pigs on both household and industrial scale farms use cages as floor cages or cages with cooling and heating systems for piglets. Feeding and nipping stages are done 72% automatically. Households breeding buffaloes and cows are fed using grass-

cutting machines for chopping straw and trees (reaching 60%). Milking machines have reached 75% of total work at dairy farming households.

High levels of mechanization and automation (from production, food processing, milk collection, and processing) and high technology applications are applied mainly in dairy companies and enterprises.

3) End-Users of agricultural machines and equipment

In Viet Nam, agricultural mechanization is low compared to other countries in the region. The level of mechanization of agricultural production in some stages is high, such as tillage, caring for rice and sugarcane, and rice harvesting. The mechanization level is comparatively low for rice transplanting, caring for fruit trees, and harvesting sugarcane and coffee.

In addition, the distribution of driving and agricultural machines is not balanced among regions, and there are significant differences in availability and efficiency of use. In the Mekong Delta, farming is mechanized mainly in the rice and sugar industry. In contrast, this rate is still very low compared with other upland crops in the Northwest and Central Highlands.

Currently, agricultural machines and equipment are used by three main groups:

- *Individual households:* This group has a small production scale and limited financial resources, and their machines' usage capability is low. Therefore, they can only equip machines for each separate production stage, mainly soil preparation, pesticide spraying, plant protection, reaping, and threshing. Households in the South use machines with a higher power source than those in the North.

The average area of rice cultivation/household in the Red River Delta: 50.04% of households have an area of less than 0.2 ha; from 0.2 to 0.5 ha, accounting for 34.79%; from 0.5 to 2 ha accounted for 12.9% and over 2 ha accounted for 2.27%. Similar is the case for the Mekong Delta: 8.49%, 29.87%, 48.2%, and 13.44%, respectively.

The rate of mechanization of agricultural production is generally low. The tractors are mainly in small size, so the utilization efficiency and the degree of multi-use of the movers are not high.

- *Cooperatives/service groups:* This model has been spreading and often provides services to fruit and vegetable production models in large fields. Agricultural cooperatives have an average production land area of 50 to hundreds of hectares.

This group uses machines and equipment with medium horsepower, which can be used for each stage separately or some stages synchronously from tilling, tending, harvesting, and drying.

- *Companies and enterprises:* These are medium and large companies in agricultural production, preservation, and processing. This group has a medium to large production scale, manages hundreds to thousands of hectares of agricultural land, has good financial resources,

and has a high level of machinery utilization capability. Some large companies, such as Hoang Anh Gia Lai International Agriculture Company (HAGL Agrico) and Truong Hai Agriculture Joint Stock Company (THAGRICO), use modern and large-capacity machines and equipment for crop and livestock production. They import most of their equipment and machinery from the USA and Europe.

Agricultural production companies formed from the state-owned farms (sugar companies, DOVECO co-delivered export food joint stock companies, etc.) have hundreds of hectares using machinery and equipment with medium to large horsepower for each stage or chain of stages from tilling, tending, harvesting, preserving, processing, etc. Sugar companies have started using high-capacity John Deer sugarcane harvesters.

4) Demand for agricultural mechanization: supporting policies

The field of 'manufacturing machinery and equipment for agriculture' is one of the nine industries' priorities for development in the period of industrialization and modernization in Viet Nam. Many policies have been issued to encourage the development of this sector, including a Strategy for the industrial development of Viet Nam to 2025 and a vision for 2035 (Decision No. 879/QD-TTg of the Prime Minister dated 9 June 2014). The industry groups selected to develop priorities in the processing and manufacturing industry are products, machinery, and equipment for agriculture and agro-forestry-fishery processing industries. Prioritization increases the processing rate of key agricultural and aquatic products and wood processing in line with the restructuring process of the agriculture sector.

The master plan on development of Viet Nam's industry to 2020, and vision to 2030 (Decision No. 880/QD-TTg dated 9 June 2014) also highlighted the importance of the agricultural machinery and equipment manufacturing industry. It is also identified as a key industry to develop to meet the basic needs of the economy. It aims to form many leading mechanical engineering corporations to take the lead to speed up industrialization in terms of market economy and international and regional integration.

The policy on implementation of a key mechanical programme focuses on several projects to develop agricultural mechanization and reduce post-harvest losses, such as manufacturing harvesters for rice and sugarcane; manufacturing diesel engines with large capacity (over 100 HP), tractors, and modern dryers. The policy contributes to ensuring the preservation requirements of rice in particular and other agricultural products in general.

In order to help businesses overcome difficulties in agricultural production, the Government added agricultural machinery and equipment to the list not subject to value-added tax. Specifically, according to Decree No. 12/2015/ND-CP of the Prime Minister and Circular No. 26/2015/TT-BTC of the Ministry of Finance, positive regulations were issued on a number of machines and specialized equipment for agricultural production, including plows, harrows; milling machines; row

slitting machines; original tarpaulin machines; equipment for leveling fields; seeding machines; transplanting machines; sugarcane planting machines; carpet coating production machine systems; cultivator, spreader, sprinkler, fertilizer machines; plant protection sprayers; machines for harvesting rice, corn, sugarcane, coffee, cotton; machines for harvesting tubers, fruits and roots; tea cutting machines; tea picking machines; threshing machines; corn peeling machines; corn threshers; soybean threshing machines; peanut shelling machines; coffee huskers; machines and equipment for preliminary processing of coffee and wet rice; dryers for agricultural products (rice, corn, coffee, pepper, cashew etc.) and aquatic products; machines to collect and load sugar cane, rice and straw in the field; incubator, hatching poultry eggs; grass harvesting machines, straw balers; milking machines, and other specialized machines.

Furthermore, to stimulate demand for machinery, equipment, and materials for agricultural production, the Government has issued a number of policies to support interest rates on commercial loans for long-term, medium-term, and short-term. These loans are for purchasing machines, equipment, and materials for agricultural production to improve productivity and efficiency and reduce losses in agriculture (Decisions 497, 63, 65, 68 of the Prime Minister and Government Resolution 48, etc.). The support objects are organizations, businesses, cooperatives, cooperative groups, households, and individuals who take loans to buy machines and equipment for the production, preservation, and processing of agricultural, forestry, and fishery products. Machines and equipment included in the list are as followings:

- Machines for tilling, leveling the field, planting, tending, and harvesting rice, maize, coffee, tea, and sugarcane;
- Dryers for agricultural and aquatic products;
- Machines and equipment for clean salt production;
- Machines and equipment for animal husbandry;
- Irrigation equipment systems to save water in agricultural production;
- Machines and equipment for seed production;
- Machines and equipment for detecting fish, collecting and releasing fishing nets, communications, freezing tunnels, product storage tanks with refrigerating equipment, producing ice, filtering seawater, processing fresh water for fishing vessels and logistics service ships serving offshore fishing;
- Machines and equipment for processing products from agricultural and aquatic wastes and by-products;
- Warehouses and equipment for storage and preservation of rice and maize on a household scale;
- Tractors, diesel engines for land crops production, fishing, etc.

Decision No. 68/2013/QD-TTg dated 14 November 2013, on support policies to reduce losses in agriculture, mandates that the state budget support the difference between commercial interest rates for long-term and medium-term loans in Vietnamese Dong and the State's investment credit interest rate to implement investment projects to invest in machinery and equipment to reduce agricultural losses. The maximum loan amount for the above

projects is 70% of the project's value. According to reports from localities, the number of agricultural machinery and equipment under support of this policy is 25,000 pieces of which tractors, tillers, and rice harvesters account for 93%.

Decree No. 55/2015/ND-CP introduces credit policies for agricultural and rural development. Individuals, households, cooperative groups, business households, cooperatives, unions of cooperatives, and farm owners are entitled to unsecured loans by credit institutions at different levels.

Policy tools to support equipment procurement are not strong enough, loans are small, procedures are cumbersome, and farmers are challenged to access them. According to survey results, only 3.5% of agricultural mechanization service households (those who need to buy large and medium-sized machines) can borrow money under this policy. In comparison, the percentage of agricultural households that borrow capital for production is 34.4%. This loan does not meet the actual demand because the prices of the machines that farmers need to buy are very high, e.g., a rice combine harvester costs VND 360-650 million, and a sugarcane combine harvester costs around 10 billion VND.

5) Ability to supply agricultural machines and equipment in Viet Nam

(i) Manufacturing organizations:

There are over 100 factories in the agricultural machinery manufacturing sector. Vietnam Engines and Agricultural Machinery Corporation (VEAM), under the Ministry of Industry and Trade, is the leading corporation in manufacturing prime movers and agricultural machines in Viet Nam. VEAM currently has 27 members as sub-companies in the form of a state-owned limited company.

Table 3.4.9. Products and spare parts for agricultural production of VEAM

	2016	2017	2018	2019	2020
Internal combustion engines of all kinds	53,192	63,220	34,412	36,946	27,656
Tractors of all kinds	5,158	4,579	2,974	2,006	2,039
Rice milling machine	9,900	11,439	6,170	6,637	2,928
Generator	1,434	1,199	671	459	490
Gearbox of all kinds	38,184	79,196	85,089	40,298	24,968
Water pumps of all kinds	4,562	3,293	1,914	2,083	2,092
Rice cutting machine	1,958	1,710	1,938	743	1,143

Source: VEAM 2021

THACO Agricultural Machinery Factory was established in 2017. In terms of agricultural machinery, it mainly transfers technologies from LS Mtron Group (Republic of Korea). In the first phase, the factory had an annual designed capacity of manufacturing 2,000 tractors, 3,000

sets of farming equipment, and 1,000 combine harvesters. However, the factory is still in the trial production phase, with no products widely sold in the market.

Vietnam KUBOTA Limited Company is a 100% Japanese-owned enterprise, established in 2008 and headquartered in Ben Cat, Binh Duong province. The Company operates in the distribution and assembly of agricultural machines such as tractors, combine harvesters, transplanters, sugarcane planting machines, etc.

(ii) Manufacturing ability

Currently, Viet Nam's agricultural machinery manufacturing industry has the following capabilities:

- Engines: Produces 40,000 units of diesel engines per year (occupying about 30% of the domestic market) with capacities up to 30 horsepower.
- Tractors: Small 2-wheel tractors (<15 horse-power) can be produced, basically meeting the domestic demand. Small 4-wheeled tractors (<30 horse-power) can be produced, meeting a small portion of domestic demand, most of which still has to be imported. Locally produced tractors of the size> 30 horse-power are in trial production and, therefore, are all imported.
- Water pumps: Local production of various types of centrifugal and axial flow water pumps, including hydraulic ones, meets irrigation water pumping requirements.
- Combine harvesters: There are 15 enterprises with an annual capacity of about 1,000 pieces. However, they are working at about half of their installed capacities. The domestically produced machines cannot meet the requirements of agricultural production, and many have to be imported.
- Scattered reapers: There are about six enterprises manufacturing spreader reapers that can meet 100% of domestic demand.
- Threshing machines: There are many establishments in almost all provinces in the South. In the North, the main products include three types of rice threshing machines (capacity 6,000 units/year) to satisfy domestic requirements.
- Rice milling machines: Over 90% of rice milling and polishing lines (productivity from 4-48 tons/h), and dryers (productivity from 30-200 tons/batch) are manufactured by domestic enterprises with advanced technology (Bui Van Ngo, SINCO, LAMICO, etc.). In addition, domestic companies manufacture silos for rice storage and auxiliary equipment for processing rice, with a maximum capacity of nearly 1,000 tons/silo.
- Preservation equipment for aquatic products: Equipment for refrigeration, cold storage, and fish processing are fabricated and assembled locally.
- Coffee processing equipment: Many types of machines and equipment, such as drying machines, advanced coffee processing (steam, wet polishing) equipment, coffee roasting systems, and instant coffee processing equipment systems (productivity from 125 kg/h-1,000 kg/h) are manufactured by some enterprises like Vina Nha Trang Mechanic and Viet Hien Mechanic. The number of machines and equipment produced covers part of coffee processing mechanization

requirements in the country.

- Rubber processing: Domestic mechanics can provide 85% of the demand for natural rubber processing equipment in Viet Nam. However, rolling machines, vibrating floors, and baling presses from Viet Nam can be exported to other countries, such as Africa (branch of MICHELIN Company), Indonesia, Cambodia, etc.

(iii) Weaknesses

Despite the achievements, the industry of machinery and equipment manufacturing in agricultural production and processing has many weaknesses in Viet Nam including;

- Size of enterprises: most of the manufacturing enterprises of agricultural machines are small enterprises, accounting for 53%, microenterprises 35.8%, and medium enterprises 44% (Viet Nam Institute of Agricultural Engineering and Post Harvest Technology – Chu Van Thien, 2016). The weaknesses of the businesses of small enterprises are (1) low capital and often a lack of floating capital for production, (2) low quantity and quality of labor, and (3) lack of specialization and cooperation since the manufacturing companies are mostly self-contained.
- Number of products: According to the government's target, domestically manufactured products were expected to meet 45-50% of the demand by 2010. But until now, only 30% of the domestic demand is met by domestically manufactured products.
- Quality and design: Although a number of machines and equipment produced locally are relatively of good quality and accepted by the domestic market, yet in general, the quality and designs of most machines are poor and incomparable to those imported ones from Japan and Republic of Korea.
- Price: Prices of many locally produced machines and equipment are high and cannot compete with similar ones that are imported from other countries, especially from China.

(iv) Import and Export market

a) Import and Export of agricultural machines and equipment

Currently, Viet Nam has a trade deficit in agricultural machinery. Main machines used in agriculture are graders, bulldozers, land development machines, 4-wheel tractors, combine harvesters, transplanters, tea harvesters, insecticide sprayers, etc. Nearly 100% of equipment lines for tea, sugarcane, rubber, and wood processing, and 40% of diesel engines are imported.

In 2014, Viet Nam's import of agricultural machinery from China was worth 121 million USD, accounting for 38.8% of total imports of Viet Nam. After China, Viet Nam imported from EU countries (59 million USD, accounting for 18.9%), Japan (41.6 million; 13.3%), and ASEAN member countries (mainly from Thailand, 27.7 million USD, accounting for 8.9%).

Regarding the structure of imported products, processing machines, combine harvesters, livestock equipment, and tractors usually account for a high proportion of the total import turnover of agricultural machinery in Viet Nam.

Table 3.4.10. Imports of Agricultural machinery

Unit: 1000 USD

Type of machine and equipment	2016	2017	2018	2019	2020
Agricultural, horticultural or forestry machines for tillage or farming	20,153	11,894	15,979	16,811	14,328
Plows	6,893	1,157	1,512	1,948	1,934
Harrows, rakes, cultivators, weeders and hoes, disc harrows	24	207	218	243	200
Seeders, planters and transplanters	1,357	1,711	2,220	1,479	2,469
Fertilizer spreaders	265	494	367	336	177
Harvesters or threshers, including straw or hay bundler or baler and fresh or dry lawn mower	111,264	114,617	91,182	60,187	68,036
Straw or hay bundler or baler, including machines for lifting (collecting) packed bales	4,450	5,210	2,640	1,518	2,471
Other harvesters; beaters; Combine Harvesters	80,045	75,793	59,602	27,033	27,883
Other beaters	93	84	180	254	659
Root or tuber harvester	197	658	79	391	179
Other machines for agricultural, horticultural, forestry, poultry production or beekeeping, including seed nurseries incorporating mechanical or thermal equipment; poultry incubators and newly hatched poultry heating equipment	108,458	102,698	94,885	128,680	102,135
Animal feed processing machines	61,495	43,423	38,316	37,414	29,256
Machines for cleaning, sifting or sorting seeds, cereals or dried legumes; machines for milling and processing of cereals or dried beans	31,330	41,091	32,072	42,757	26,203
Machines for cleaning, sifting or sorting seeds, cereals or dried legumes	23,216	22,552	19,183	21,017	16,646
Tractors	351,210	261,589	67,273	174,284	188,190
Hand Tractors	1,437	3,345	3,749	4,055	3,781
Other tractors	319,027	53,229	45,024	35,530	39,219
Total	1,120,914	739,752	474,481	553,937	523,766

Source: Vietnam Customs (2022)

Imports are mainly from China, EU, Japan, and ASEAN countries. Viet Nam has to import nearly 70% of agricultural machinery, most of which is from China. Compared with the same types,

domestically produced machines are 15-20% more expensive than the Chinese machines.

In terms of the exports of agricultural machinery, the volume is far lower than the import volume. Below are some of the export destinations of the machines and equipment produced in Viet Nam:

- Plows (mainly made in Viet Nam by Kubota and Yanmar – Japan): exported to Philippines, Malaysia, Singapore, Sri Lanka, Australia, Italy, Germany, France, USA, Canada, Colombia, Lebanon, Iran, and Tanzania.
- Seeders, planters, and transplanters: exported to India, Malaysia, Indonesia, Thailand, Sri Lanka, Mongolia, USA.
- Other harvesters, beaters, and combine harvesters (mainly made in Viet Nam by Kubota- Japan): exported to the Philippines, Pakistan, Japan, Colombia, Tanzania, Togo, Dominican Republic. Other beaters to United Arab Emirates; Hong Kong, China; Republic of Korea; Bhutan; Guinea; Lao PDR.
- Root or tuber harvesters: to Myanmar, Ethiopia.
- Machines for cleaning, sifting or sorting seeds, cereals or dried legumes: to Philippines, Malaysia, Singapore, Indonesia, Cambodia, India, Ivory Coast.
- Hand Tractors: exported to Philippines, Myanmar, Lithuania, Sri Lanka, India, Bangladesh, Japan, Germany.

Table 3.4.11. Exports of Agricultural machinery

Unit: 1000 USD

Type of machine and equipment	**2016**	**2017**	**2018**	**2019**	**2020**
Agricultural, horticultural or forestry machines for tillage or farming	11,290	15,762	12,729	13,755	13,476
Plows	3,398	4,566	1,334	1,637	1,934
Harrows, rakes, cultivators, weeders and hoes, disc harrows		45	16		109
Seeders, planters and transplanters	264	172	199	237	293
Fertilizer spreaders	6	31		1	40
Harvesters or threshers, including straw or hay bundler or baler and fresh or dry lawn mower	9,935	15,506	15,288	20,860	404,572
Straw or hay bundler or baler, including machines for lifting (collecting) packed bales	13	15	3	62	264
Other harvesters; beaters; Combine Harvesters	5,609	10,148	8,067	3,869	7,113
Other beaters	52	44	3	21	72
Root or tuber harvester	3	9			
Other machines for agricultural, horticultural, forestry, poultry production or	8,917	11,053	14,224	11,348	12,115

beekeeping, including seed nurseries incorporating mechanical or thermal equipment; poultry incubators and newly hatched poultry heating equipment					
Animal feed processing machines	832	1,671	3,370	2,925	5,357
Machines for cleaning, sifting or sorting seeds, cereals or dried legumes; machines for milling and processing of cereals or dried beans	27,336	24,759	25,920	21,732	24,890
Machines for cleaning, sifting or sorting seeds, cereals or dried legumes	5,104	3,502	2,407	2,421	4,561
Tractors	10,026	16,339	14,098	14,557	15,626
Hand Tractors		49	2,152	1,014	2,575
Other tractors	10,016	13,187	11,446	12,375	11,979

Source: Vietnam Customs (2022)

b) Prospects and opportunities for cooperation

1) Main exporting countries to Viet Nam

- China: Importing agricultural machinery from China is important for the Vietnamese market. Chinese agricultural machines are highly adaptable and affordable. Therefore, they are convenient for Vietnamese farmers. The main imported products are gardening machines, combine harvesters, livestock equipment, processing machines, and beverage machines. However, at present the trend of using machinery imported from China tends to decrease due to issues in quality, spare parts, and after-sales service.
- EU: The EU-Vietnam Free Trade Agreement (EVFTA) has been fully validated since 2020 to facilitate trade between EU and Viet Nam including importing agricultural machines and equipment. Currently, the trend of importing agricultural machinery and equipment from the EU market is decreasing, mainly due to price issues. On the other hand, EU countries also tend to shift industrial production, including agricultural machinery manufacturing, to overseas (especially labor-intensive industries with low added value). It is forecasted that imports from the EU will increase in value, but the proportion will continue to decrease. Imports will focus on agricultural and food processing machines and equipment.
- Japan: Japan is an important and strategic partner of Viet Nam. In the recent period, the import of agricultural machinery and equipment from Japan has increased sharply due to quality, adaptability, and efficiency in use. In forecasting the next stage, imports from Japan will continue to grow, both in value and proportion, focusing on tractors, field graders, transplanters, pesticide sprayers, gardeners, combine harvesters, and food or beverage processing machines.
- ASEAN: In agricultural machinery and equipment, it is forecast that Viet Nam will increase imports from ASEAN countries like Thailand, Malaysia, and Indonesia.
- Republic of Korea: Agricultural machinery

imported from Republic of Korea is increasing. Viet Nam and Republic of Korea have also signed the Free Trade Agreement, which promises to promote bilateral trade between the two countries. Currently, the Korea Agricultural Machinery Industry Corporation (KAMICO) is interested in promoting the export of large 4-wheel tractors, combine harvesters, sprayers, seeding machines, etc., with the most modern technology to Viet Nam. In the future, imports from Republic of Korea are likely to grow strongly.

Table 3.4.12. Import share of agricultural machinery to Viet Nam

	China	Japan	Rep. of Korea	USA	EU	ASEAN	Others
2014	37.0%	14.1%	3.7%	3.6%	19.9%	8.8%	13.0%
2020	33.0%	18.0%	6.0%	5.0%	16.0%	12.0%	10.0%
2030	28.0%	19.0%	10.0%	5.0%	15.0%	14.0%	9.0%

Source: Nguyen Manh Linh (2016)

2) Main imported products

Table 3.4.13. Forecast of import demand by products

Type of machines and equipment	Forecast of import demand
Simple tools, milling machines, threshers, etc.	Those can be actively produced domestically, so their import turnovers in the next period are likely very small
Equipment for spraying, or pressure spraying for agricultural use (pesticide and spraying)	Demand will increase slightly in the next period. The main import sources are China, Japan and ASEAN countries
Machines for tilling or planting	Import demand is low, focusing mainly on transplanting machines and earthmoving machines
Harvesting machines, machines for cleaning, sorting or selecting agricultural products	Import demand is high. Mainly combine harvesters (Thailand, Japan, China), machines for cleaning and classifying agricultural products, lawn mowers (Japan, USA, China)
Milking and milk processing machines	Import demand may increase
Machines used in the production of beverages	Import demand is moderate with the main source of imports from China and EU
Other machines used in agriculture, forestry and animal husbandry	Machines with high demand including animal food processing machines (China, EU), and those used for animal husbandry (China, EU)
Machines for cleaning, selecting or sorting seeds and grains	Demand will increase in the coming period. Import sources are China, Japan and ASEAN
Machines for industrial processing or for	The types of machines are in the highest demand. The

Type of machines and equipment	Forecast of import demand
the production of food or beverages	import sources are diverse, and the proportion of imports from Japan; Republic of Korea, China, EU, and ASEAN countries are likely to increase.
Tractors	Tractors are in high demand, imported mainly from Japan, Republic of Korea, USA, and China.

Source: Nguyen Manh Linh (2016)

Table 3.4.14. Specific past and forecast of import shares of agri. machines

	2014	2020	2030
Equipment for spraying, or pressure spraying for agricultural use (pesticide and spraying)	9.1%	7.0%	4.0%
Harvesting machine, machines for cleaning, sorting or selecting agricultural products	14.9%	16.0%	18.0%
Other machines used in agriculture, forestry and animal husbandry	12.6%	11.0%	10.0%
Machines for cleaning, selecting or sorting seeds and grains	10.2%	12.0%	10.0%
Machines for industrial processing or for the production of food or beverages	31.3%	31.0%	34.0%
Other tractors	9.6%	14.0%	14.0%
Others	12.2%	9.0%	10.0%

Source: Nguyen Manh Linh (2016)

Until 2020, the primary import demand was still industrial processing machines, harvesting machines, and tractors. The share of imports of other products mostly decreased or remained the same.

Viet Nam does not have many service facilities for specialized mechanical machines; technical operations and repair of modern agricultural machinery still have many limitations. Meanwhile, vocational training to operate agricultural machines has not been given sufficient attention. Maintenance of machinery is essential as it helps extend the machine's life and makes it work with greater efficiency. The machinery of foreign-invested companies in Viet Nam, such as Kubota and Yanmar has good after-sales service, and they have a team of professional maintenance staff, so technical support through training, after-sales service, and spare parts supply are performing better than the other companies.

6) Sustainability

Decision No. 150/QD-TTg, signed on 28 January 2022 by the Prime Minister, approved the Strategy for Sustainable Agriculture and Rural Development for 2021-2030, vision to 2050. It is expected that by 2030, the GDP growth rate of

agricultural products will reach an average of 2.5-3%/year, and the productivity growth rates of agricultural workers will reach an average of 5.5-6%/year. Markets, especially export markets, will be expanded. The export values of agro-forestry-fishery products are expected to reach an average of 5-6%/year.

The Strategy sets out orientations and tasks for developing general cultivation, rice production, husbandry, aquaculture, and forestry by 2030. In all these sectors, mechanization is crucial to achieve these respective tasks, creating an enabling environment for the sustainability of agricultural mechanization development.

In addition, the Strategy emphasizes the importance to develop a green and environment-friendly agriculture, which is not easy to achieve. At the same time, mechanization can play a significant role in attaining agricultural sustainability. Below are some examples:

- For rice production by traditional farming practice, farmers burn straw in the field after harvest instead of collecting straw for animal feed, processing and producing fertilizer. That causes environmental pollution and degradation of productive land. The increased use of combined harvesting and straw baling machines and equipment minimizes burning and increases farmers' income. Currently, some localities have been applying 4.0 technology in farming stages by using uncrewed aerial vehicles for sowing, fertilizing, and especially for spraying pesticides, increasing agriculture's efficiency and precision.
- For irrigation, economical watering and automatic irrigation systems are widely applied to ensure uniform supply, especially to limit fertilizer loss.
- For soil preparation, minimum tillage is used to reduce soil surface disturbance and soil erosion.

In general, to cope with the requirement for sustainable agriculture and rural progression, the development of sustainable agricultural mechanization is a must, for instance by investing in technological innovation and modernizing mechanization applying science and technology, especially 4.0 technology and advanced quality management systems. Thus, policy support is imperative to ensure the sustainability of the agricultural mechanization development.

7) Conclusion and Recommendation

(i) Conclusions

This paper has given a brief overview of the agricultural mechanization sector in Viet Nam, such as land use, planted areas for main crops, production status of main crops, and the export and import volumes of agricultural machinery in recent years. Viet Nam has achieved good export turnovers of agricultural machinery, and it can be seen that the development of agricultural mechanization has been concretely contributing to the achievements. The demand for agricultural machines and equipment is clearly seen through the information on the number of agricultural machines and equipment used in the last five years. However, needed machines and equipment are mostly imported from other countries such as China, Japan, Republic of Korea, USA, etc.

The machines and equipment use trends on the way to 2030 are forecast below:

- 4-wheel tractors would replace 2-wheel tractors.
- 4-wheel rice transplanters would be used instead of 2-wheel transplanters.
- Combine harvesters are used instead of harvester spreaders/reaper-windrowers.
- Combine harvesters are also used for sugarcane.
- Hi-tech, water-saving equipment, and automation will be upscaled in farming.
- Plant protection equipment will be used with motorized unmanned aerial vehicles.

The annual machinery demand will be increased for each type by 2030, specifically as follows:

- 2-wheel tractors (under 15 HP): an average increase of 5%/year (about 10,000 units). This type of machine is suitable for small arable land areas. The investment capital is not significant (20-35 million VND/unit), so it will continue to increase in the coming years, and since 2020, the demand for 2-wheel tractors has increased more than 4-wheel tractors in small arable land areas.
- 4-wheel tractors (from 20 HP or more): an average increase of 5-8%/year (5,000-8,000 units). As estimated, this machine will increase by 2025 because agricultural production will speed up with better investment conditions and improved field infrastructure.
- Combined rice harvesters (with a working width of 1.8-2m) are mainly used in the Mekong Delta, Red River Delta, Central Coast, and concentrated agricultural production provinces. In small and scattered farmland areas, from now to 2030, combine rice harvesters will gradually replace rice harvesters with a working width of 1.2-1.6m. In the Mekong Delta provinces, the demand for rice combine harvesters will increase rapidly in the future, about 2-3 times compared to the number of existing machines (an increase of 10,000-15,000 units). The demand for harvesting machines for sugar cane, coffee, corn, beans, and peanuts has increased by 3-5 times since 2015.
- Drying machine: To reduce post-harvest losses in volume and improve the quality of agricultural products, especially rice, it is necessary to focus on investing in the drying stage. The total demand for agricultural dryers, concentrated in the Mekong River region, is about 1,000 units with a capacity of 100-200 tons/day/unit, meeting the demand of processing 12-12.5 million tons of rice/year.

(ii) Recommendations

To achieve synchronous mechanization and modernization at all stages of agricultural production, from pre- and post-harvesting to processing and preservation, Viet Nam has to set clear objectives in the short and long terms. And how to develop agricultural mechanization sustainably is more important and needs to be paid more attention.

In order to do so, the agricultural machines and equipment which are conducive to reducing energy cost, labors, and waste released to the environment while ensuring productivity and efficiency should be developed and promoted. In particular, these machines and equipment include:

- Land preparation: mostly 4-wheel tractors with productivity, efficiency, and favorable working conditions.
- Planting and transplanting stages: Gradually shifting from sowing with tools to using tray-plated rice transplanters and high-speed rice transplanters. Use machines for sowing corn and planting sugarcane, etc.
- Caring stage: Use current plant protection sprayers with motorized spraying equipment. Use multi-purpose tractors for caring (e.g. shoveling).
- Irrigation stage: Apply water-saving irrigation technology (drip irrigation, sprinkler irrigation) for sugarcane, tea, coffee, and other industrial crops.
- Harvesting stage: mainly use combine harvesters with high technical features and a high level of efficiency. For corn, sugarcane, cassava, and peanut harvesting, use 1-2 row machines.
- Drying and preservation stages: Developing all kinds of dryers suitable to the production scale and level with the aim to reach an annual rice drying capacity of over 20 million tons.
- The demand for the machines and equipment will likely increase dramatically in 5 to 10 years ahead. However, the capacity to produce them in the country is far lower than the demand. Therefore, many of the machines and equipment should be imported from other countries as specified in the above parts. To overcome the problem of the imbalance between imported and locally produced machinery, in the near future the government should pay more attention to the volumes, quality, and cost of all kinds of machines and equipment to decide what to import and what to produce domestically. At the same time, related policies shall be developed to facilitate the import process of agricultural machines and equipment, such as reduction of import tax, easing custom procedures, and so forth.
- Loans with low or zero interest rates shall be considered, targeting companies or groups of farmer households who need to buy agricultural machines and equipment. For the domestic production capacity, there should be support for producers who apply advanced, intelligent, precision, and environment-friendly technologies. The support can be a reduction of taxes (especially for companies who employ a large number of females and persons with disability), favorable loan interest rates from banks, and free training courses for companies' employees and farmers (conducted by government agencies) on how to operate and maintain the machines and equipment, and other related issues including environment protection.

IV. Summary, Conclusions, and Recommendations

Agricultural mechanization is a vital input in modern agriculture and an economic activity capable of enhancing the quality of life and enriching added value from the efficient use of natural resource base. This has been taken well into consideration while orchestrating national development frameworks of almost all countries studied (Bangladesh, Nepal, Russian Federation and Viet Nam), which intend – albeit at varying levels – to facilitate agricultural transformation from the current high-input, high-output, low-efficiency, and unsustainable development mode to a high-yield, good-quality, high-efficiency, ecosystem-friendly and food securing one.

The agricultural machinery market is determined by the demands and aspirations of farming and allied enterprise communities. The potential clients may choose the type, size, and make of machinery that suits them the most for their business needs. The manufacturers respond by developing and marketing the most demanded machinery by the end-users who would also look for ready availability of spare parts and after-sales services. Furthermore, one way of promoting sustainable crop production intensification is to enable active participation of the private sector through entrepreneurs in agribusinesses and agricultural mechanization operations.

This study provides insights into the demand and supply of agricultural machinery and the industrial responsiveness of the end-users. It highlights current mechanization levels regarding the major crops grown in the target countries and identifies potential areas for future growth. This knowledge base is useful for producers, promoters, traders, and end-users, including hiring service providers of agricultural machinery to nurture their businesses in the region.

The agricultural machinery market helps us draw the attention of stakeholders by capturing the scale at which it is practiced in a country. The estimated sizes of the annual current markets are valued at 5.3 billion USD, 1.28 billion USD, 0.056 billion USD, and 0.524 billion USD for the Russian Federation, Bangladesh, Nepal, and Viet Nam, respectively. The Russian Federation is a significant producer of agricultural machinery, followed by Bangladesh and Viet Nam, while Nepal is a net importer in this context. Rice, wheat, jute, and rapeseed & mustard are the principal commercial crops in Bangladesh, whilst these include rice, maize, wheat and sugarcane in Nepal; rice, maize, sugarcane and groundnut in Viet Nam; and wheat, sugar beet, potatoes and cereals (maize, barley and oats) in the Russian Federation. The information on crops grown, together with the extents of their cultivation and respective agro-technological and socio-economic conditions of each country, help in pointing towards the development and use of specific agricultural machinery with appropriate capacities and technology levels. Therefore, high-capacity agricultural machinery is used in the

Russian Federation while small-to-medium scale machinery is in vogue in the rice-dominant economies except for combine harvesting in Viet Nam and Bangladesh, primarily due to custom hiring.

A. SWOT Analysis

1) Strengths

- The supply chain of agricultural machinery is generally well structured and established across the markets of most countries studied. The supply chain stakeholders are playing their respective roles in taking the technologies from producers to the end-users and helping them identify future market preferences. The intermediaries also facilitate linking them up with the financial institutions for their effective growth. The introduction of 'custom hiring service centers' by all countries studied has remarkably paid high dividends, especially by taking the technologies to the doorsteps of smallholders. However, there is room for improvement so long as spare parts and repair and maintenance (R&M) services are available, especially in Nepal's market. Bangladesh appeared to have somewhat avoided the issue by localizing the production of critical parts.
- Custom hiring provision of high-capacity and multi-featured agricultural machinery in the private sector is quickly making inroads in mechanization to be scale-neutral. Mechanization services providers are generally experts in the operation and R&M of complex machinery. They thus, ensure services are far superior to what a farmer-owner can render for themselves. Furthermore, the farmers are relieved of worrying, especially about the machinery's ownership costs (depreciation, tax, insurance, and shelter).
- An average to medium-sized network of dealers is available for marketing and after-sales servicing of agricultural machinery in all four countries studied.
- The subsidies provided by the governments for the purchase of agricultural machinery have considerably helped farming, manufacturing, and services communities in triggering the pace of agricultural mechanization in the countries under review, albeit at varying levels. The distributors in Nepal, however, cast their fear of making any substantial sales once subsidies are withdrawn.
- Relatively high-capacity agricultural machines are used in the Russian Federation owing to the farming type and size. Around 60% and 30% of cropped areas, amounting to 52.4 million ha and 25.6 million ha are raised by Agricultural Enterprises (commercial) and Peasant & Individual entrepreneur farms (Groups & Cooperatives) respectively.
- A high level of mechanization in the Russian Federation has been achieved in the main field operations like tillage, grain drilling, potatoes, and sugar beet planting, harvesting of grain, fodder, potatoes, beets, silage crops, and haylage besides mechanization of labor-intensive operations in livestock husbandry like preparation and distribution of fodder, milking, removal, transportation and processing of manure. Poultry farming has been the most mechanized and automated Russian sector.
- In 2021, Russian farmers were not only able to meet the country's grain, meat, vegetable oil,

and fish needs, but also exceeded production requirements of a number of other agricultural products enshrined in the Food Security Doctrine adopted in early 2020.

- The minimum support price of the staple crops grown is a healthy indicator influencing agricultural machinery demand. All Governments of the four countries studied practice this to mitigate the risks associated with the price decline and crop failures. The Russian Federation has taken a step further in this regard by developing and practicing an agricultural risk insurance portfolio, which includes all types of crops, seeds, and unsold crops, including those transported to procurement centers. This is especially true for the risk farming areas of the country where effective farming is difficult owing to the extreme climatic conditions.
- Agricultural mechanization in Viet Nam, Bangladesh, and to some extent in Nepal is graduating to the second stage of mechanization as most of the farm operations requiring high to medium levels of power and low to medium levels of control (tillage, seeding, irrigation water pumping, spraying, inter-row operation, grain harvesting & threshing, transport, milling etc.) stand substantially mechanized. Whereas the Russian Federation has almost reached the third, i.e. last stage by having mechanized all of the farming operations, including the ones requiring a high level of control and low level of power (e.g., transplanting, harvesting of sugarcane, cotton, fruits etc.) except for vegetable production.
- The foreign remittances appear to hold high potential for the upgrade of agricultural mechanization by the private sector in the three rice producing countries, provided attractive enabling environments are made available through policy instruments.
- A positive insight evident from portfolios of the countries studied is that almost all have realized the importance of mechanized agriculture by embedding it into their national development policy frameworks.

2) Weaknesses

- Inefficient agricultural machinery hampers farm profitability due to several factors including low productivity and time-consuming high operating costs. Farming in the Russian Federation is realized using outdated machinery; the shares of grain harvesters, forage harvesters, and tractors older than ten years in the available fleet stood around 59%, 60%, and 68%, respectively. Therefore, most farmers look towards State interventions to help them acquire state-of-the-art, efficient and digitalized farm machinery enabling them to enhance the global competitiveness of Russian food products.
- Low levels of mechanization in the areas of land leveling, paddy stand establishment, crop management and harvesting (especially in the non-paddy segment), horticulture, and value addition have been observed in the three rice producing countries with a notable exception in the level of mechanized paddy transplanting uptake (65%) in Viet Nam.
- The high cost of financing hampers the agricultural mechanization promotion drives due largely to the low creditworthiness of the smallholders. Furthermore, they are

considered high-risk (natural and market) clients by most traditional financing institutions unless substantial collaterals are pledged. Almost all countries in this study have resorted to facilitating the farmers' machinery purchase through subsidy and lease programs. Alternatively, the provision of custom hiring services in the private sector with some financial backup from the public sector has helped mechanization gain momentum in the countries under study for enhanced machinery access even by the smallholders, although with some compromises on timeliness. Most participating countries indicated no great dearth of financing in formal and informal sectors except for some pointing towards a genuine need to allocate pre-determined financial outlays exclusively for such clients, preferably at discounted rates.

- The rice producing countries in the study highlighted an urgent need for capacity-building in their light engineering industry, including R&M services providers and farmers, to improve their business management skills and technical competence for efficient operation of their respective enterprises.

3) Opportunities

- There is a common realization amongst the rice producing countries in focus that the agriculture sector holds a high potential to ensure food security of their growing populations, provided sustainable development for primary production and value chains takes place in tandem with appropriate mechanization. This provides an opportunity to not only attract back youth into farming but also enable them to transform agriculture from the current high-input, low-output, low-efficiency, and unsustainable development model towards a high-yield, good quality, high-efficiency, ecosystem-friendly, and food secure one. Smart farming and precision agriculture, once capitalized, could prove to be game changers by engaging and empowering rural unemployed, educated and skilled youth, including women, owing to a more productive and remunerative agriculture.
- The option of land consolidation, especially in the subsistence and small farming segments through policy intervention, appears to offer another effective way for not only working towards ensuring food security but also reducing the incidence of hunger and poverty in the rice dominant countries. The experiences gained from the initiatives taken by Viet Nam and, to some extent, by Nepal reinforce this argument, besides the impressive reorientation of the farming outlook in Viet Nam towards high-value agriculture in conjunction with the upgrade of the industrial sector.
- The 'Think global and act local' approach holds a vast hidden potential to sensitize agricultural machinery markets' dynamism, especially in the rice producing countries under review. Viet Nam seemed to lead the race by working towards VietGAP and having inked several trade facilitation agreements by gradually diverting their resource base penetrating some of the high-end markets. The pattern of end-user profiling in Viet Nam seemed identical to that of the Russian Federation.
- The new development avenues, including e-commerce, can help the manufacturing and

trading communities expand their businesses remarkably to new markets while staying informed with the latest developments worldwide.

- There is a need to build the capacities of the end-users, including entrepreneurs in developing systematic business plans for effective utilization of machinery acquired through public support and ensure optimum returns of their investments in the rice-producing countries studied.
- There is an acceleration in the rate of out-migration of the agricultural workforce to the other sectors, creating labor shortages at the peak demand periods in the rice-dominant countries. This trend is likely to continue in the coming years, thereby creating further demand for the mechanization of different farming operations in these countries.
- Indiscriminate use of natural resources such as land, water, air, biodiversity, and ecosystem services in agricultural intensification has not only resulted in the decline of yields and some factor productivity growth rates, but also aggravated their environmental footprints. Conservation Agriculture (CA), a knowledge-intensive approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and environment is foreseen to become the standard agricultural production system globally in not that a distinct future. Therefore, the countries under review would need to factor in this aspect through effective adaptation and diffusion of CA technologies in their food production systems.

4) Threats

- A critical challenge for mechanization development practitioners in the target countries other than the Russian Federation is to develop machinery appropriate to the fast-emerging needs of marginalized and fragmented small landholders (a vast majority holding less than 1ha), due mainly to inheritances. However, small-scale machinery such as power tillers and compact tractors have helped dealing with such situations in the short run.
- The low-quality, small-scale imported agricultural machinery and the non-availability of their spare parts in the local markets of rice dominant countries threaten the long-term machinery service and sustainability of mechanization. The manufacturers should enhance the quality of their machines and ensure the availability of spare parts and maintenance services through their distribution channels for sustainable mechanization.
- The urbanization trend of youth to non-agricultural sectors for better wages, working, and living conditions has been quite evident in all four countries. Thus, agriculture is left largely to an aging workforce and women. Consequently, farm profitability is in jeopardy due to labor shortages and wage hikes, especially during critical farming times.
- Inclement weather conditions also have a bearing on the demand for agricultural machinery. A classic case in the limelight is that of Bangladesh, which was a blessing in disguise. As a result of a national food crisis after a cyclone hit Bangladesh in 1988 within two and half years of a previous one, taking not

only a major toll on human life but also on the draught oxen population, the government liberalized the agricultural machinery market and lowered the tariffs, resulting in the massive import of small pump-set engines for irrigation and later power tillers and other equipment. These developments, coupled with the widespread use of tens of thousands of small-scale mechanized rice and wheat threshers and maize shellers - mainly powered by Chinese diesel pump-set engines, enabled Bangladesh not only to avert the crisis situation but also changed drastically the mechanization landscape of the country besides creating substantial employment opportunities in other rural and urban sectors.

- Energy availability from fossil fuels at exorbitant costs is fast becoming a hindrance to upscaling of mechanization technologies in most countries. The mechanization promoters should, therefore, explore the alternate renewable resources for contributing towards an energy mix to help the end-users protect the degrading natural environment.

B. Recommendations

This section presents the recommendations emanating from the main findings and conclusions of the study. The main focus is on highlighting and reinforcing the roles of major stakeholders in stimulating the national agricultural machinery markets along the mechanization inputs supply chain i.e., manufacturing, trade (local & foreign), service industries, and farming communities in the countries studied.

The recommendations pertaining to the Russian Federation are presented separately on three distinct counts compared to the rest of the countries. One, the advanced food security level; two, the agricultural mechanization level i.e., almost touching the third or final stage; and three, the negligible rate of rice production in the agriculture portfolio.

1) Russian Federation

The key recommendations include:

- focusing on the mechanization of vegetable production and value addition;
- replacement of around 70% of the old tractors and 60% of the grain and forage harvesters respectively, of the country's fleet with the most modern ones alongside their regular service and replenishment plans;
- upgrade of agro-industrial complexes for quality enhancement of agricultural machinery using top-of-the-line production technology and quality human resources (qualified and skilled); and,
- continued facilitation of the end-users in the acquisition of the latest agricultural machinery through enhanced subsidy and preferential leasing and loan programmes of the State.

2) Bangladesh, Nepal and Viet Nam

A national agricultural machinery market can only be considered vibrant and growing when it is profitable for all the stakeholders, namely, machinery manufacturers, traders, importers, distributors, dealers: R&M service providers, operators, and farmers. The overarching role of

the public sector through orchestrating the enabling environment for nurturing the private sector in leading mechanization cannot be overemphasized either. The reinforced roles of public and private sector entities in this context with regard to the three rice-based economies studied are proposed:

(i) Public Sector

Policy support envisaged towards:

- land consolidation and mechanized farming, especially in the subsistence-smallholder segment;
- provisioning of an enabling environment for the creation and nourishment of rural entrepreneurship related to the promotion of agricultural mechanization, especially by educated youth including women; and,
- establishment of Common Facility Centres in industrial hubs in partnership with the manufacturing industry for quality enhancement of local products and indigenization of imported machinery and components.

Finance

The governments need to ensure the availability of sufficient credit at soft rates to all the stakeholders including small farmers in the promotion of agricultural mechanization technologies. This facilitation needs enhancements in extending smart subsidies for accessing agricultural machinery through direct ownership and custom hiring windows. International financial institutions may be approached for long-term financing at concessional interest rates, if needed.

Taxes

Provide incentives such as:

- tax holidays for attracting FDI in establishing JVs for quality machinery production;
- duty-free import of agricultural machinery, including tractors and spare parts;
- rebate on the duty paid for the specialized but verifiable materials used in agricultural machinery manufacturing; and,
- discounts on the energy tariffs for agricultural machinery manufacturing.

Subsidies

Consider enhancing and extending the smart subsidies, preferably in a public-private-partnership mode, for the diffusion of mechanization technologies in making farming profitable for ensuring worldwide competitiveness in agricultural products trade.

Research and Development

Reorient agricultural mechanization R&D by:

- equally valuing the voices of research engineers, manufacturers, and end-users, including farmers as partners in product development and adaptation for swift commercialization;
- small-scale agricultural machinery be developed and commercialized for serving the mechanization needs of the hill farmers;
- the ICT- and satellite-based mechanization interventions, including robots and drones, be developed, adapted, and adopted for the promotion of precision farming, especially in changing climate adaptation and minimizing environmental footprint contexts;
- enhance alternate use of farm energy sources from renewable ones for the promotion of sustainable agricultural mechanization;

- mainstream women in the development and efficient operation of agricultural mechanization technologies with emphasis on pulses and horticultural production and primary processing; and,
- prioritize agricultural machinery management research.

Capacity-building

Ensure capacity-building of the stakeholders from:

- agricultural light engineering industry in business management and technical skills;
- end-users, including custom hire servicing entrepreneurs in developing business plans for effective and sustainable utilization of agricultural machinery accessed primarily through public support; and,
- farming communities in efficient farm planning and management.

(ii) Private Sector

Manufacturing

Enhance interaction of the local manufacturing industry with farming, agricultural machinery development (both local and international), and academic communities, besides exploring digital platforms for future products. Upgrade the HR competencies and level of manufacturing technology used in the industry for quality production of agricultural machinery, duly exploring the untapped potential of the auto-parts vending industry in indigenizing the critical components.

Importers and Distributors

Upgrade business management systems of importers and distributors using modern business tools and systematic market approaches such as customer feedback, price sensitivity analysis, and periodic reviews of the after-sales services. Capacity-building of the customers be made an integral part of their business plans.

Dealers

A network of authorized dealers not only helps marketing of machinery but also plays a pivotal role in ensuring the quality of after-sale servicing and sourcing of genuine spare parts in their territories. Periodic capacity-building of the dealers' relevant staff could be ensured by imparting hands-on quality training in proper on-field adjustments, repair and maintenance of the machinery. For resource use optimization and customer facilitation, the concept of authorized multi-brand dealer centers, as practiced in the Russian Federation and Nepal, is also recommended for Bangladesh and Viet Nam.

Repair and Maintenance Servicing

Repair and maintenance of agricultural machinery is another key activity in the supply chain performed beyond warranty periods. Most countries studied reported shortages of such facilities, including their technical competencies e.g., for efficiently handling mini tillers, rice transplanters and combine harvesters in Nepal. This area deserves special attention from both sectors for ensuring timely, quality and cost-effective machinery repairs in the remote areas.

Custom Hiring Servicing

Hire service providers venture to bridge the farmers' mechanization needs on what can

potentially be met using available machinery from the market. Therefore, it is rewarding to encourage and nurture them through capacity-building in technical and business management skills, ensuring optimum utilization of the available resources besides incentivizing the unemployed, educated rural youth and women to venture into such avenues in a public-private-partnership mode. The hallmark of successful hire service providers impinges upon their close and vibrant working relationships with their customers and smart networking with the rest of the agricultural machinery market stakeholders.

Farmers

Though the end-users or farmers sit at the end of the supply chain, they have an exceedingly important role in adopting mechanization technologies, whether simple or complex in design and construction. Their needs and aspirations must be met through ownership or hire to gain their confidence in valuing the mechanization inputs, hence keeping the market up and growing. A well-informed and trained farmer with an appetite for maximizing his farm profits using mechanization interventions through the local market is always a blessing for the entire value chain.

Way forward

With increased threats to the natural resource base, especially in a changing climate context, present-day agriculture had become far more complex than ever before and needs to be better equipped to effectively respond to the needs and aspirations of farming and allied communities. Each unit of resource input ought to be invested optimally with far more wisdom using appropriate mechanization gadgetry for harnessing the agricultural potential of a fast-changing world. Though farmers and technicians, together with other stakeholders along the food value chains, are contributing immensely in playing their specific roles, a more dedicated effort is imperative with seamless coordination, vigor, and harmony for effective and timely achievement of the SDGs.

Countries in the Asia-Pacific region have marked their presence on the horizon of global economic development. A regional rather than national perspective may be worth considering in achieving economies of scale in local manufacturing by encouraging the emergence of small-scale commercial farming. Promoting of regional cooperation among agricultural communities, manufacturing, trading and service industries will therefore be beneficial in accelerating the pace of agricultural mechanization for contributing to the global economy and promoting joint efforts in effectively dealing with the emerging challenges. A vast optimally untapped potential is poised for technical and trade leveraging in the Asia-Pacific region for working towards ensuring food security, reducing hunger and poverty. Innovative plans are thus called for based on the conceptualization of the policy analysis where the specifics of local contexts play a vital control, whether these be agro-technological, socio-economic, commerce and trade conditions, or political contexts. Viet Nam seems to have embarked on such a track by aligning its economic landscape with the local and high-end markets through diversification of agriculture and value addition in commensuration with the

valuable natural resource base. Agriculture in the region seems set for transformation from subsistence to semi-commercial, but 'by design'. Smart farming i.e., the application of intelligent Information and Communication Technology (ICT) systems, such as sensors, the Internet of Things (IoT), cloud-based processes, machine learning, networking and Artificial Intelligence (AI) is being progressively dovetailed into such endeavors for boosting production and efficiency, promoting sustainability, expanding the agricultural industry to benefit rural and farming communities, and assuring that the products meet market needs while maximizing profits and lowering production costs. Within the farming system, such technologies affect crop production, livestock, and aquatic farming by increasing farm output, gathering weather data, monitoring crop growth, early detection of crop diseases, preventing crop waste through efficient crop harvesting, monitoring livestock behavior patterns, tracking animals inside and outside of farms, and increasing production of both crops and livestock. Based on autonomous systems, these technologies efficiently regulate actuators, improve utility, and control usage. A few such applications include developing an IoT-based soil moisture monitoring system, irrigation water quality monitoring of water bodies, and real-time field performance, including seeding depth monitoring of agricultural mechanization technologies.

Computers, the internet, social media, smartphones, robotics, sensors, and cloud-based processes have revolutionized how society organizes itself and how individuals and groups behave and make decisions. Agricultural and food production systems are not immune to this digital revolution and are forecast to undergo significant changes in the future. Considering the growing need for research and innovation in this area, it is crucial to be mindful of the potential socio-economic and cultural implications that may arise consequent upon using such technologies in smart farming.

Information Communication Technologies (ICTs), in particular, hold high potential in helping them catch up fast with the desired and sustainable levels, especially by exploring and capitalizing on the opportunities unfolding for agricultural machinery manufacturing, trading, and service provision communities through effective networking in the region. Keeping in view different levels of economic development, scales of landholding, cost of finance, gender and other relevant market forces, producers of machinery and consumers of such machinery must consider appropriate mechanization to suit local agro-technological, socio-economic, environmental, and industrial conditions. It is therefore important to have a thorough understanding of the market dynamics, including consumer types and their behavioral patterns, crops and cropping patterns, the extent of mechanization, and the gaps, to ensure that the farmers have access to appropriate technology at competitive prices and that the researchers and producers are able to effectively contribute towards sourcing such requirements. In other words, the suppliers of agricultural mechanization technologies must consider the design, economics and socio-cultural aspects and adapt their products that meet such differences, qualifying eventually to sustainability.

Similarly, it is necessary to identify the needs, aspirations, and challenges of smallholders and marginalized groups, including women farmers, as opportunities for niche market development concerning agricultural mechanization. Low affordability levels coupled with resource-poor financial conditions of such end-users have been reckoned as serious impediments to their development. Gender issues in agriculture have seldom been recognized as a mainstream concern because rural women are not afforded their due stature in agriculture policy-making. Despite realizing that a sizeable proportion of the agriculture workforce in many countries of the Asia-Pacific region comprises women, the influence of mechanization on gender is not addressed adequately in development planning. Rural women are generally constrained in accessing mechanization technology design due to limited avenues for education, information, and services. Therefore, a sound understanding of the existing and potential markets becomes of utmost importance.

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